

UNCLASSIFIED

AD. 286 505

*Reproduced
by the*

**ARMED SERVICES TECHNICAL INFORMATION AGENCY
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA**



UNCLASSIFIED

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

63-1-2

286 505
286 505

FABRICS FOR COATING

MILITARY APPLICATIONS

*Committee on Textile Fabrics
Advisory Board on Quartermaster
Research and Development*

ASTIA APPLICATIONS FILE 1 "UNLIMITED"
REQUESTERS MAY OBTAIN COPIES OF THIS
REPORT FROM ASTIA."

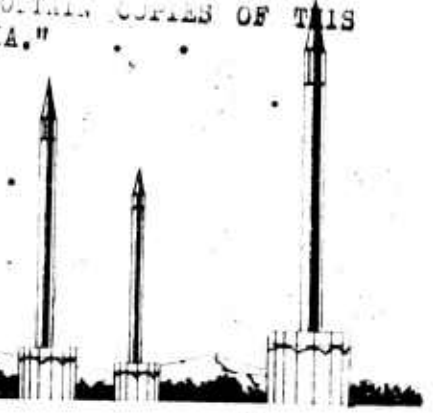


ASTIA

OCT 24 1962

ASTIA

B



NATIONAL ACADEMY OF SCIENCES—
NATIONAL RESEARCH COUNCIL

FABRICS FOR COATING

Military Applications

Proceedings of a Conference

QUARTERMASTER RESEARCH

AND

ENGINEERING CENTER

NATICK, MASSACHUSETTS

October 16-17, 1958

Sponsored by

Headquarters Quartermaster Research and Engineering Command

U. S. Army Quartermaster Corps

and

Committee on Textile Fabrics

Advisory Board on Quartermaster Research and Development

Division of Engineering and Industrial Research

Edited by

FRANK R. FISHER AND STANLEY BACKER

NATIONAL ACADEMY OF SCIENCES NATIONAL RESEARCH COUNCIL

Washington, D. C.

1959

This publication is available from the
HEADQUARTERS QUARTERMASTER RESEARCH
AND ENGINEERING COMMAND

Natick, Massachusetts

Library of Congress
Catalog Card No. 59 60088

Opinions expressed in the conference on *Fabrics for Coating* are those of the individual contributors and do not necessarily represent the views of the Academy Research Council or of the Quartermaster Research and Engineering Command.

PREFACE

A technical program devoted entirely to the subject of Fabrics for Coating should include topics of interest to the fiber industry, the spinning and weaving plants, the manufacturer of coating materials, the coater, the end item fabricator, and the consumer. Such a program would be considered too restricted for sponsorship by any professional society associated with the classical fields of science and engineering. The same program, in turn, would be considered too broad for presentation by an industry-oriented professional society in, say, the fields of textiles.

As an advisory group servicing the Quartermaster Research and Engineering Command in the field of textile fabrics we were convinced that the Committee on Textile Fabrics could provide an ideal vehicle for sponsorship of such a cross-industry discussion. This became evident, to our gratification, in the attendance at the conference of numerous competent individuals with associations ranging from the raw material manufacturer to the ultimate consumer of coated fabric materials. The result has been an interesting two-day program punctuated with stimulating question sessions.

It is hoped that the published proceedings of the conference will provide a useful collation of ideas and facts for workers in the field of coated fabrics. One can expect that a repetition of this conference in a few years will significantly advance the cross-fertilization initiated here. Or, as one attendee remarked, the application of the information presented here can best be realized through subsequent conference treatment of the specific problems of the fabricator of coated fabric items.

• Stanley Barker
• Chairman
Committee on Textile Fabrics

CONTENTS

	<i>Page</i>
INTRODUCTORY REMARKS	
W. George Parks, Executive Director, Advisory Board on Quartermaster Research and Development	1
Colonel H. S. Wofford, Deputy Commanding General, Quarter- master Research and Engineering Command	2
Stanley Backer, Chairman, Committee on Textile Fabrics	3
 TECHNICAL SESSION NO. 1	
ARMY APPLICATIONS OF FABRICS FOR COATING	7
Stephen J. Kennedy, Quartermaster Research and Engi- neering Command, Natick, Massachusetts	
NAVAL APPLICATIONS FOR COATED FABRICS	30
Robert Grubb, Philadelphia Naval Shipyard, Philadelphia, Pennsylvania	
THE ROLE OF COATED FABRICS IN TODAY'S AIR FORCE	40
Jack H. Ross, Wright Air Development Center, United States Air Force, Dayton, Ohio	
DESIGN FOR CLIMATIC EXTREMES	54
Austin Henschel, Quartermaster Research and Engineering Command, Natick, Massachusetts	
INTERACTIONS OF FABRICS AND COATINGS	60
Milton M. Platt, Fabric Research Laboratories, Dedham, Massachusetts	
 TECHNICAL SESSION NO. 2	
FABRICS FOR COATING—DESIGN AND CONSTRUCTION	83
William A. Corry, The Landers Corporation, Toledo, Ohio	
NEW FIBERS AND FABRICS FOR COATING	97
Rexford C. Pike, Textile Fibers Department, E. I. duPont de Nemours & Company, Wilmington, Delaware	
 TECHNICAL SESSION NO. 3	
TECHNICAL ADVANCES IN COATING MATERIALS FOR FABRICS	117
F. H. Fritz, Elastomer Chemicals Department, E. I. duPont de Nemours & Company, Wilmington, Delaware	

CONTENTS

TECHNICAL PROBLEMS OF THE COATER.....	145
Joseph L. Haas, Hodgman Rubber Company, Framingham, Massachusetts	
EVALUATION OF END ITEM PERFORMANCE.....	161
K. L. Keene, United States Rubber Company, Mishawaka, Indiana	
TECHNICAL SESSION NO. 4	
SUPPLEMENTARY PRESENTATIONS	
CHARACTERISTICS OF VINYL AND NITRILE COATING MATERIALS AS WELL AS A LOOK AT SOME NEWER PRODUCTS.....	189
Lawrence L. Shailer, Jr., B. F. Goodrich Chemical Company, Cleveland, Ohio	
BUTYL RUBBER IN PROOFED GOODS APPLICATIONS.....	192
Stanley R. Shuart, Enjay Company, Inc., New York, New York	
THE LAMINATE STRUCTURE.....	197
David H. Schafer, Weblon, Inc., New York, New York	
COMMENTS ON FIBERS	
William Whitehead, Celanese Corporation of America, Charlotte, North Carolina.....	201
O. Douglas Schumann, American Enka Corporation, New York, New York.....	204
DISCUSSION.....	207

INTRODUCTORY REMARKS.

W. George Parks

Ladies and gentlemen, good morning and welcome to the Conference on Fabrics for Coating.

A word may be in order on the connection of the National Academy of Sciences -- National Research Council with this meeting. Briefly, in 1942, during World War II, the Quartermaster General went to the National Academy of Sciences and asked for advice and assistance on some of his research and development problems. The National Research Council, which is the operating agency of the National Academy of Sciences, responded enthusiastically, setting up what is now an Advisory Board on Quartermaster Research and Development. The Board has established a number of committees to furnish advisory service in the various areas in which the Quartermaster is interested. The particular committee active this morning is the Committee on Textile Fabrics.

The Committee normally meets several times a year to consider, with Dr. Kennedy and his staff, the Quartermaster research and development program in the area of textile fabrics. In addition to the more or less regularly scheduled committee meetings, from time to time the Committee organizes and sponsors, jointly with the Quartermaster Corps, a conference on some timely, important subject. That is the background of the conference this morning.

We are very happy the conference has aroused as much interest as we thought it would when we first started talking about it six months or more ago.

On behalf of the National Academy of Sciences -- National Research Council, I sincerely welcome you to this Conference. I hope you will have a very profitable two days. I hope you will participate in the discussion and have questions which may develop discussion to further this problem of fabrics for coating.

Now it is my pleasure to introduce the individual who will extend the official welcome on behalf of the Quartermaster General and the Quartermaster Research and Engineering Command. It gives me pleasure to introduce to you Colonel H. S. Wofford, Deputy Commanding General of the Natick Quartermaster Research and Engineering Command.

Colonel H. S. Wofford

Thank you, Dr. Parks and good morning ladies and gentlemen. On behalf of General Calloway, our Commanding General, who is in Washington today, I bid you welcome to Natick and, particularly, to the Research and Engineering Command.

The application of fabrics for coating in this Command has received considerable assistance, in the past, from groups such as this, from industry, from private laboratories, from other Government agencies, and from universities. We are very appreciative of that help which has come to us from those sources. We feel that coated fabrics, as applied to tentage and to individual equipment of soldiers, have great potential in solving many of our clothing and housing problems. But, beyond that, we feel that the future use of coated fabrics in the housing of missiles, in the housing of rockets, and other special equipment is going to be a still more important area. The coated fabric to be used by crews servicing and fueling missiles and rockets is going to be one of great importance to this group.

The need for good specifications to cover these fabrics is of great importance to the Quartermaster Corps. In order that the

end product may perform the function for which it is intended, it is of grave importance that we start out with a sound set of specifications. We feel that this conference can contribute significantly to the development of these specifications in the future, just as you have in the past on an individual basis.

We are glad that you are here with us today and hope you will have a good meeting. We expect a great deal of good for the Quartermaster Corps will derive from this conference.

Dr. Parks: Thank you, Colonel Wofford. It is now my pleasure to turn the meeting over to the Chairman of the Committee on Textile Fabrics, Dr. Stanley Backer from the Massachusetts Institute of Technology.

Stanley Backer

Thank you, Dr. Parks. It is good to see so many people in attendance at this session today. We were a bit concerned as to whether a subject possessing such a wide coverage would provide sufficient points of interest for as many people as have come today.

The cross-section of the audience, based upon the registration list, indicates some seven groups are present: first, the fiber people, synthetic fiber manufacturers and growers of the natural fiber; second, those who weave cloth, the textile manufacturers; third, the coaters, who apply coatings to the cloth; fourth, the manufacturers of the coating material; fifth, the users of the end item, the military services and also the civilian users; sixth, we have the person who fabricates end items from the coated materials; and finally, in the seventh category, we have those who are just plain curious. We welcome all seven categories of attendees.

The technical emphasis of this conference is on the textile fabrics which are used for coating by the military services. It is difficult to divorce the question of fabric behavior from the

properties of coating materials, but we shall attempt to underline the importance of textile cloth as the basic component in the composite structure known as a coated fabric. The textile structure is a system characterized by high component mobility or free movement between fibers and between yarns. In mating the cloth with a continuous film or coating material we interfere with that mobility and radically alter the mechanical properties of the resultant system. Such changes create serious problems for the coater, the fabricator of end items, and the military or civilian user.

The conference program is broken down to three phases. First, we are concerned with a positive definition, by various branches of the Armed Services, of the requirements for fabrics for coating. The second phase of the program has to do with the fibers which serve as structural elements in the fabric for coating. It also deals with the importance of fabric geometry and the interaction between fiber properties, and structural design of a cloth intended for coating.

The third phase relates to the properties of coating materials, specific problems in coating cloths to meet rigid specifications, and testing techniques in evaluation of coated fabric behavior.

As to the conduct of the conference, I would like to suggest that your questions be withheld until the formal question periods. Each of you has a large card, issued to you with your registration materials. It would be appreciated if you would write your questions on the card, first indicating your name and organization at the top, then the person to whom the question is directed. We will collect the cards from time to time and separate them so as to group questions directed at a single speaker in an attempt to develop a discussion in regard to his topic. We suggest this scheme because the schedule does not allow for interruptions prior to the question period. In addition to the cards, we will

entertain questions from the floor which are stimulated by the questions submitted in writing.

TECHNICAL SESSION NO. 1

Stanley Backer, presiding

Chairman Backer: It is my pleasure this morning to present, as the first speaker, the Head of the Textile, Clothing, and Footwear Division of the Quartermaster Research and Engineering Command of Natick, Dr. Stephen J. Kennedy. I believe he needs no further introduction. I am sure his paper will serve as an excellent start for the conference.

ARMY APPLICATIONS OF FABRICS FOR COATING

STEPHEN J. KENNEDY -- Graduated from the University of Illinois with a B.A. in 1926. He attended Columbia University where he received a M. A. in 1931 and Ph.D in 1936. Dr. Kennedy has been associated with the Quartermaster since World War II, and presently is Director of Research, Textile, Clothing, and Footwear Division, Quartermaster Research and Engineering Command, Natick, Massachusetts. In addition to being a member of various Textile Societies, here and abroad, Dr. Kennedy is a member of the American Chemical Society and the American Economic Association. He is the author of *Profits and Losses in Textiles*, 1936; *Textile Markets* (with Hiram S. Davis and others), 1938; and contributes articles for Trade and Scientific publications.

The fact that we are considering "Fabrics for Coating" in these discussions, instead of "Coated Fabrics", is itself significant. It indicates the recognition, for one thing, that the proper application of fiber and yarn properties to the engineering of the base fabric structure is of fundamental importance to the functional performance of the combined fabric-coating system. Also, it

reflects the progress that has occurred in textile fabric engineering in recent years, as well as the great increase in the capabilities of the textile industry which has stemmed from the creation of new fibers with new properties and the improvement of properties of existing fibers.

To see the role of textiles for coating in military applications, one needs to turn back to World War II and to review the types of coated textiles then used in military items, the studies which were made at that time in this general field, and the changes in use-requirements since that time and their effect upon required fabric properties.

These various uses for coated fabrics can be grouped into four general classes:

1. Clothing uses.
2. Small, lightweight tents and covers.
3. Frame-supported tents, paulins and covers.
4. Specialty uses, e.g., coated fabrics for air bags, water containers, etc.

Clothing Uses. Let us first consider clothing uses. Of these the most notable one, from the standpoint of development, has been the Army raincoat. Until shortly before the outbreak of World War II the Army soldier was provided with a raincoat made of a double-texture fine-count cotton fabric bonded with a layer of rubber. By 1941 this had been changed to a single-layer-coated cotton-print cloth or sheeting. However, questions of whether to coat both sides of the fabric, of depth of coating, of adhesion, of aging characteristics, and other factors had not been settled, when the nonavailability of rubber made it necessary to change to a polyvinyl chloride coating. (Later this was extended to polyvinyl butyral.) This change to a new coating material created new problems of cold-temperature properties, freedom from tackiness

at high temperatures, adhesion, sealing of seams, and others.

Also, the problem of low tear strength of the coated fabric became accentuated. Just what the best coating formulation should be, to obtain the most serviceable coating and to minimize loss of tear strength, became an urgent question. It is not surprising, accordingly, that one of the first broad research projects undertaken by the National Research Council Committee on Quartermaster Problems was to initiate a broad survey of coated fabrics.

This project, undertaken at Brooklyn Polytechnic Institute, and identified as QMC-36, had as its objective the evaluation of new developments in the coated fabrics industry that might be applied to the improvement of coated fabrics for Quartermaster Corps items. The report of this project, issued in December 1945, reported test data on 153 coated fabric samples; some samples taken from actual production of raincoat materials to serve as a measuring stick for the experimental samples, and the other samples representing experimental formulations of many different types.

A related event was the series of lectures on protective coatings given under the sponsorship of the Research and Development Branch of the Office of The Quartermaster General in 1943-44 for all individuals in the Government Agencies concerned with the development or use of coated fabrics and organic coatings in general.

A significant thing about this research program and the series of lectures, and in fact, the whole range of studies conducted during World War II on coated fabrics, was that practically the entire effort was focused on the coating -- very little on the fabrics. For example, the final report on the QMC-36 project listed test samples as follows:

1. Nineteen samples of vinyl-coated nylon twill.
2. Seventeen samples of polyvinyl butyral-coated nylon twill.

3. Six samples of SBR-coated nylon twill.
4. Eleven samples of butyl-coated nylon twill.
5. Three samples of neoprene-coated nylon twill.
6. One sample of Buna N-coated nylon twill.
7. Fifteen samples of vinyl-coated cotton sheeting.
8. Nineteen samples of polyvinyl butyral-coated cotton sheeting, and so on.

There was one group of twelve samples on miscellaneous fabrics including a rip-stop nylon, parachute nylon, MM balloon cloth, HH balloon cloth, Fortisan, and Fiberglas.

These fabrics, as most of the fabrics used for coating tests during the war, had been developed for other purposes and were tried out for coating because of availability, rather than fabrics specifically developed or engineered to serve as a base for coating. This emphasis upon the coating is shown further by the tests that were applied to the coated fabrics produced under QMC-36. They were tests concerned with the finished product in which the contribution of the coated material could not be readily determined.

1. Strength, flexibility, and hydrostatic characteristics before and after various aging tests, including Florida exposure, desert storage, and tropical storage.
2. Low-temperature flexibility, crack resistance, and durability.
3. Wyzenbeek abrasion resistance.
4. Blocking characteristics.
5. Change of flexibility and appearance occurring in accelerated aging tests.
6. Coating adhesion.
7. Flammability.

Of course, consideration was given to the possibility of using a lightweight nylon-fabric base for coating. Seconds of parachute canopy fabric were tried; however, the adhesion was not satisfactory, indicating that a more open construction was required.

The possibility of changing the weave of the cotton fabric by use of rip-stops, plying of nylon and cotton yarns, and other devices was considered, but practical problems in manufacturing or coating or both prevented adoption of a specially designed cotton fabric at that time.

In 1943 the poncho was adopted as a field item of equipment for protection against rain. The advantages of using a lightweight, strong, tear-resistant fabric for coating were over-ridingly apparent since it had to be expected that the poncho would catch on underbrush in field use. A 1.6 oz nylon fabric had been developed during the war years for the parachute canopy fabric but it was not considered a satisfactory construction for coating. A similar fabric of approximately the same weight was developed utilizing 70 denier nylon yarn in both warp and filling. This was adopted as the best fabric for coating for the poncho.

During this period the concept of textile fabric engineering for specific uses began receiving wide attention. The notable Marburg Lecture by the late Harold De Witt Smith in 1943 had focused attention upon studies which had already been underway in England at the Shirley Institute. Also, Quartermaster studies on wear resistance conducted by Fabric Research Laboratories and the discovery that proper employment of fabric construction could greatly increase the serviceability of textiles in clothing showed how important it was to understand the mechanism of fabric properties in various end uses.

This led to the undertaking of a project on coated fabrics by the Fabric Research Laboratories for the Quartermaster in 1946 -- to determine the effect of weathering on the tear and tensile strength of coated fabrics. As the study progressed, it was directed toward a general investigation of the mechanism of tear strength of coated fabrics. The findings of this study brought out,

for the first time, the significance of fabric construction and geometry upon properties of the coated fabric.

However, during this period no new fabric was adopted for the poncho, partly because of the obvious need to find a more thermally-resistant coated fabric so that the poncho could be used as a shield or shadowing device against high-intensity thermal radiation. In 1956 a coated 2 oz Fortisan fabric in a plain weave was utilized for a test of a new poncho which would be resistant to thermal radiation and gas. This fabric utilized a balanced construction, 48 x 49, utilizing 150 denier yarn and giving an overall weight of 8 oz/sq yd with a neoprene coating.

After the war the World War II raincoat continued to be an item of general issue for semidress wear. However, as part of the re-development of the Army uniform to improve its appearance, it was decided that a dress type raincoat should be developed for general wear by all troops. This raincoat, which is presently in the process of production, utilizes a 1.6 oz nylon fabric very similar to the standard Type II parachute fabric. The nylon for the filling yarn is required to be preshrunk to minimize barre effects, since the fabric appears on the outer side of the raincoat which is single-side coated with polyvinyl butyral. The total weight of the raincoat is approximately 1 lb in average sizes. It promises to be a very popular item as well as presenting a very satisfactory appearance with the service uniform.

In addition to the raincoat and poncho, coated fabrics have been used in other applications in military clothing, particularly in rain-proof garments, chemical protective garments, and more recently in clothing for fuel handlers of guided missiles (Fig. 1). The Chemical Corps' impermeable protective suit, designed for crews handling toxic agents, utilizes conventional fabrics of the types which have been used in the past for coating. These include such fabrics as



Fig. 1. Clothing for fuel handlers of guided missiles.

lightweight cotton airplane cloth, cotton sheeting, and a nylon twill. However, when the protective clothing for fuel handlers of guided missiles was developed several years ago, the suit originally adopted by the Army utilized a 5.4 oz Fiberglas fabric to which a vinyl coating had been applied. Protection was required

against such oxidizers as red fuming nitric acid, aniline, and hydrazine. Experience with this suit demonstrated that the Fiberglass material when made up into a garment was undesirably heavy since it had to be coated on both sides. The fully protective suit recently adopted as a replacement for the earlier model utilizes a conventional cotton airplane cloth coated with a modified butyl resin. This coated fabric weighs 10 oz/sq yd as compared to 18 oz/sq yd for the coated Fiberglass, resulting in a reduction in weight of the suit of approximately 4 lb.

For impermeable protective handwear the conventional approach, until recently, has been to use either an unsupported rubber glove, or, if fabric base was required, to follow commercial practice in utilizing either a Canton flannel or sheeting. Recently the availability of warp knit fabrics for coating has afforded the opportunity for achieving an elastic coated fabric. Such a fabric structure is presently being considered for certain types of protective handwear by the Army. In view of recent Army developments in the field of handwear, including the development of the anthropometric-shaped hand and handwear developed to fit the normal relaxed position of the hand, such elastic constructions appear to give an optimum approach to dexterity and freedom from fatigue in the hand when wearing impermeable type handwear.

The physiological problem posed by the wearing of an impermeable clothing system has presented a most difficult problem to all of the Armed Services which, at one time or another, have had a requirement for a fully protective suit. The fact that neither air nor water vapor will pass through coated fabrics reduces convective heat losses by either conduction or evaporation and offers resistance to the passage of water vapor when the body is sweating at a high level and approaching heat stress. In hot climates the heat stress is so severe that some form of cooling is definitely

required. Many attempts have been made to devise a cooling system for such an impermeable clothing outfit. Studies conducted at the Harvard Fatigue Laboratory during World War II established certain characteristics of impermeable suits. For example, at a temperature of 84°F men could not wear such clothing more than 25 minutes. However, by keeping the outer surface of the suit wet with water the tolerance time could be doubled. Advantage has been taken of this fact in our acid and fuel handlers clothing by the use of an outer cotton fabric which can be soaked with water so that, by evaporative cooling, the skin temperature of the man wearing the suit could be lowered substantially under conditions of high external thermal stress.

The requirement to maintain fuel handlers of guided missiles in hot climates in such fully protective suits has led this Command to the development of a cooling system based upon the use of liquid air. It is believed that, with the use of such equipment, impermeable clothing systems may become more widely usable where definite hazards from toxic agents may exist and safety requirements dictate the wearing of a fully protective suit.

In cold climates, at normal activity levels, the condensation of moisture under the impermeable fabric has been, at the very least, disagreeable and has resulted in loss of insulating efficiency of the clothing system. This problem of the impermeable protective suit in cold climates has been attacked from another angle. In contrast to the permeable clothing system approach through the use of tightly-woven cotton fabrics, a semi-impermeable coating system was explored during the years immediately after World War II. Out of this development an over-extended or discontinuous coating was developed by Goodyear under a Quartermaster Corps contract. The coating was found to possess a water vapor permeability 60% that of the untreated fabric. However, this coating,

known as Vapotex, has had the disadvantage of relatively poor resistance to abrasion and thereby subject to damage from severe wear. Fabrics for the Vapotex treatment have, up to this time, followed conventional cotton or nylon constructions.

Small, Lightweight Tents and Covers. The possibility of using coated fabrics for small tents arose during World War II in the attempt to supply a small, very lightweight tent for mountain troops. The tent which was developed -- Tent, Mountain, Two-Man -- was conceived as a reversible tent, white on one side for snow camouflage and dark green on the other side for other types of terrain. This camouflage requirement was critical in view of the lack of protective cover in typical mountain terrain.

In the original development of the tent in 1942, HH cotton balloon cloth was adopted as the fabric for coating. The importance of lightness in weight was emphasized. This fabric was only 2 oz in weight and it was desired to apply a coating which would give a total weight not to exceed 3.8 oz/sq yd. This was accomplished by bleaching the fabric, leaving it white on one side and applying a colored pigment coating on the other side. Later, this procedure was reversed with the fabric blotch-printed in green on one side and white pigmented resin applied to the other side. Later, a slightly heavier airplane cloth using plied yarns was considered for the tent to increase the tear strength. At the end of 1943, when nylon became available for uses other than parachutes, the 1.6 oz nylon fabric, which was later used in the poncho, was adopted for this tent. It should be noted that during the course of this development the possibility of using nylon parachute fabric seconds was considered, but because of the problem of adhesion where such a light coating was being applied, these seconds could not be used. It should be noted that the coated cotton fabric tents were quite unsatisfactory because of their low tear strength and also the

failure of the very thin coating to withstand outdoor exposure to sunlight. The coating stiffened; the fabric became papery; and, in some cases, the loss of strength was so great that the tents were quite unusable. The tent as finally produced at the end of the war was a double coated nylon fabric, with a white coating on one side and a green coating on the other. Its use was later extended to include requirements for a small tent for the Arctic as well.

Unfortunately, this tent proved to be unsatisfactory when used in the field. Moisture condensation from the breath of the occupants or from cooking proved to be quite objectionable, whether it was in the form of water droplets which dropped on the occupants or dampened their clothing, or in the form of hoar frost which rained down on their faces. The item became quite unpopular and a firm requirement was established; that, because of this condensation problem the tent should be made from a permeable fabric. This requirement still holds and the present item in our supply system is made from a fine densely-woven cotton fabric.

A second somewhat similar use which developed during World War II was the jungle hammock (Fig. 2). It also could be classified in the realm of small tentage as it provided a shelter and hammock support for troops operating in hot wet or jungle areas. Here, there was a requirement for protection against heavy rainfall. This item also started with an upper deck made from a coated cotton fabric, but later it was changed to the same coated 1.6 oz nylon fabric used in the poncho. While the complete hammock weighed only 5 lb and provided the equivalent of sleeping gear and a tent, the hazard of using it in areas subject to enemy infiltration militated against its effective use in forward combat areas. It was used to some degree as a ground cover. However, after the war a decision was made to drop it as an item of field equipment, even though it was continued to be regarded by troops in jungle areas as a very well-liked item.



Fig. 2. Hammock-shelter.

The use of coated fabrics in small tents must be regarded as of rather doubtful validity. This problem of condensation appears to apply also to somewhat larger tents such as those of the dimension of our five-man tents which are hexagonal tents with a diameter of approximately 13 ft. In fact, any small cold-climate tent with a number of occupants and a stove would be subject to this same problem of moisture condensation. Whether it would be possible to take advantage of the lightness in weight and high strength of coated fabrics for such uses is problematical at the present time. If the premium of reduction in weight and bulk is sufficient, it may well be that the disadvantage of moisture condensation might be disregarded to permit the use of these materials in place of heavier, less water-resistant fabrics.

Frame-Supported Tents, Tarpaulins and Covers. The earliest Army use of a coated fabric for a frame-supported tent occurred during World War II with the development of the Tent, Surgical, Operating, Truck. This was a special tent designed for use by a surgical operating team whose equipment was carried in a specially designed

truck. The tent was intended to provide an operating room directly adjacent to the truck. As originally developed, this tent had the requirement of being capable of complete black-out for use at nights. Also there was a requirement for an integral floor which would reduce the possibility of dirt and dust interfering with surgical operations within the tent. The tent was provided with a liner made from a 8.25 oz shelter tent duck coated white on one side and OD 7 on the other. This coated liner fabric weighed approximately 12.1 oz/sq yd. The floor cloth was a No. 8 duck also coated with a vinyl resin to give a final finished weight of 27 oz/sq yd. The tent itself was a conventional FWWMR treated fabric. Actually this tent never got beyond the experimental stage as only a small number were produced, and it was found to be quite impracticable for use in hot climates due to the difficulty of ventilating, the lack of permeability of the deck fabric, and the problem of moisture condensation.

The second application of a coated fabric in this general area was in the development of the Red Cross marker. There were actually two items, one a tarpaulin to be placed across the ridge of a tent in a manner similar to a tent fly, presenting on each side of the tent deck the Red Cross symbol to denote that the tent was being used for hospital purposes. The other was a large tarpaulin, 100 x 100 ft in size, to be staked to the earth to form a large red cross to identify a group of buildings or an area as being employed for hospital purposes. This mark of identification was based upon the Geneva Convention whereby such hospital areas would be free from military attack. The fabric used was the 9.85 oz/sq yd duck coated to a finished weight of approximately 50% above that weight. In addition to the red coating for the cross, the background area was coated white. It may be noted that this is an ideal type of item for a lightweight coated fabric, to reduce weight and bulk in carrying in the field.

A third major application of coatings to tent fabrics occurred in the development of the 16 ft wide frame-type tent commonly known as the Jamesway shelter. Tents of this type produced during World War II utilized a 9.85 oz duck with a vinyl coating to a total weight of 14.5 oz/sq yd. In the production of the Quartermaster Corps items which were used extensively during the Korean war, this same vinyl-coated duck fabric was utilized. It was given a fire-resistant treatment with antimony oxide and chlorinated paraffin prior to application of the vinyl coating. This fabric has continued to be the specification material for this particular item up to the present time.

The possibility of applying coated fabrics to tarpaulins has also been explored. Some consideration was given to it during World War II but fabrics of suitable tear strength were not available at that time. Recently, experimental tarpaulins have been made from a 5 oz plain weave nylon base fabric coated with neoprene to an overall weight of 15 oz.

There are four problems in connection with using tarpaulins over a stack which, as yet, have not been solved successfully. The first is the problem of moisture condensation which can be very troublesome in high humid areas or where stacks consist of materiel subject to rusting or possible fungus growth. While it is possible to construct the stack to permit ventilation, this is not a normal or practicable procedure under actual field conditions. Also, there is the problem of abrasion where the tarpaulin is lashed down, either because of instability of the stack and its tendency to shift in high winds, or the actual tensions of the lashing rope that may cause an abrading action at the point of contact. This can lead to wearing away of the coating with resultant leakage. A third problem is that of tearing along the seams or points of tension. Unfortunately, coated fabrics are always weaker at sewn seams than conventional types of textiles. Presumably this problem can be overcome by the

use of wholly cemented seams, if present techniques of cementing have reached a point where they can be depended upon completely in place of sewing. It should be also noted that in using lighter weight tarpaulin fabric, particularly in coated fabrics which lack the essential stiffness of a FWWMR-treated cotton fabric, the very lightness in weight encourages the formation of pockets which will hold water. The weight of this water adds a further strain to the paulin at points of contact or where there is a protruding corner which, in turn, may lead to puncture or abrasion and failure.

Another solution to providing a tarpaulin is the use of an unsupported film. This also has been considered, and while not directly applicable to our subject today, it may be mentioned that tests have been made of unsupported film tarpaulins. These appear to present much the same type of problem as the coated fabric tarpaulin.

The principal area of potential use of coated fabrics in tents lies in the area of the larger size tents, such as maintenance shelter tents for wheeled and tracked vehicles, rotary wing Army aircraft, and fixed wing Army aircraft. Other potential uses include check-out, inspection, and storage shelters for guided and ballistic missiles. Two types of construction are presently under test: frame-type shelters, and air-supported shelters; the latter being wholly supported by a continuous flow of air at low pressures, without the use of any internal or external supports.

The first of these types, which in a sense is typical, is the longitudinal arch frame-type tent (Fig. 3) which we have developed for maintenance of wheeled and tracked vehicles. This tent, referred to as the lightweight metal-frame maintenance tent, utilizes a magnesium or aluminum frame in order to minimize weight and increase the ease of erection. The problem of weight and bulk is very critical in these larger shelters, both from the standpoint of



Fig. 3. Maintenance Shelter, T 56-9.

getting them into the field where they will be used and making them readily portable as the unit changes location. They must be capable of being transported either by truck or by air. The latter requirement places a high premium on lightness in weight, which has encouraged our office to look to the high strength synthetic fibers to provide coated fabrics as replacements for the heavier and bulkier impregnated cotton fabrics. For example, the fabric presently being utilized for experimental and test tentage for this and similar tents is a 3 oz Dacron fabric coated with neoprene to a total weight of 10 oz. The actual fabric is a modified basket weave with two ends and picks weaving as one, alternating with single ends and picks in both the warp and filling. This is in contrast to the present 12.29 oz duck treated with a FWWMR finish to a total weight of approximately 19 oz.

Furthermore, it will be of interest to note that this fabric with the neoprene coating provides a high degree of flame resistance. With its increased flexibility, and the reduction in weight which it permits for a 20 x 64 ft size tent of 214 lb, this coated fabric has a decided advantage for military use over previous tentage fabrics. It has an important additional advantage in that the coated fabric has good cold-temperature properties which permit its use in tents which must be capable of being erected and struck

at temperatures down to -40°F . The present fire-resistant-treated cotton fabric can scarcely be unrolled from its pack at temperatures below zero. All attempts to produce a satisfactory cold-temperature, fire-resistant treatment for this fabric have been unsuccessful up to this time. Even the vinyl-coated, fire-resistant-treated 9.85 oz duck used in the Jamesway shelter is unsatisfactory from this standpoint of stiffness at temperatures much below zero. It may be noted that in these larger shelters, particularly where they may be opened up for ingress and egress of vehicles, the condensation problem does not present any serious complications.

In addition to this approach of a tent with a longitudinal arch configuration, our office has given serious consideration to the possibility of using such configurations as the geodesic dome (Fig. 4). We have, in fact, tested two different types and sizes of this type of structure. As presently designed, the geodesic dome has a very interesting feature in that the deck fabric is supported from the under side of the frame. While this construction



Fig. 4. Geodesic dome. (U.S. Army Photograph).

is intended to minimize one of the difficult aspects of the use of a fabric with a frame; namely, to reduce the points of abrasion of the fabric with the metal surface, actually it was found that considerable failure of the coating and fabric occurred at points of attachment and anywhere else where the fabric might come in contact with the metal at any time. In this particular tent configuration, the fabric is under continual omnidirectional stress because the fabric is stressed to provide the essential stability to the tent structure. When highly stressed materials are used in this way, problems of abrasion and the possibility of fabric failure are accentuated. Because of the very nature of this stress the elastomers, utilized as coatings, may tend to break down. On the other hand, although the fabric is laid over the frame in the Quartermaster frame-type tents, no high degree of stress is placed upon the fabric other than to hold it securely to the frame from the standpoint of proper tensioning of the lashing ropes.

The configuration of the Quartermaster lightweight metal-frame tent with a raised circular arch and longitudinal, modular construction has opened the way to its use for many purposes. These include shelters not only for the maintenance of wheeled and tracked vehicles for which it was originally designed, but also for rotary type aircraft which can be moved readily into the shelter by folding the blades, and for inspection and checkout of guided and ballistic missiles. We have furnished tents of this configuration for test use with the Redstone missile in 12 ft widths and for the Jupiter missile in 20 ft widths. This configuration has made possible dehumidified storage shelters for missiles, in which a coated fabric is used for the deck, liner, and integral floor. Similarly, this type of shelter has been utilized in small modular sections for a nose-in type of shelter for fixed wing aircraft. A further use, presently under development, is a portable hangar for fixed wing

aircraft. A shelter of this type would require an uninterrupted span of up to 60 ft for current types of Army fixed wing aircraft. Here, the advantages of minimizing weight will be readily apparent as well as the necessity for absolute minimum weight per sq ft of covered floor area.

One further type of shelter has received intense study by the Army, the air-supported type of tent which has been widely publicized in recent years. Several possible uses of this tent have been considered, including a vertical check-out shelter for the Redstone missile. This shelter has the unique advantage that after check-out has been completed and the missile is ready for firing, the entire tent can be removed by pulling a rip-cord, attached to a quick release fastener. The force of air holding up the shelter throws the cover away from the missile and frees the missile for firing within one minute. Another use for this type of shelter is for a field portable Radome for housing the ground control equipment including the tracking antenna and acquisition radars for the NIKE Hercules.



Fig. 5. Air-supported experimental tent.

Shelters of this type have been considered for other purposes. Undoubtedly, their use will expand in the future because in place of a frame or pins and poles, the only support unit required is a relatively lightweight blower capable of delivering sufficient air to

maintain internal pressures up to 3 lb/sq in. One such experimental tent of rather large dimension, currently being developed by the Army, will utilize a 10 oz plain weave base fabric coated to an overall weight of 25 oz (Fig. 5).

Specialty Uses. There are numerous specialty uses to which coated fabrics have been put. Mention will be made of two. One is the inflatable sleeping pad developed during World War II and still being used, which employs a 2 oz plain weave nylon fabric coated with natural or synthetic rubber to a total weight of 11.5 oz/sq yd. The critical requirement, as might be expected, is resistance to the formation of pin holes or other leaks which would cause deflation of the air pad or mattress during the night. Actually the present construction is being restudied at the present time in order to achieve reduction in the convective currents inside the pad which have reduced its insulating value.

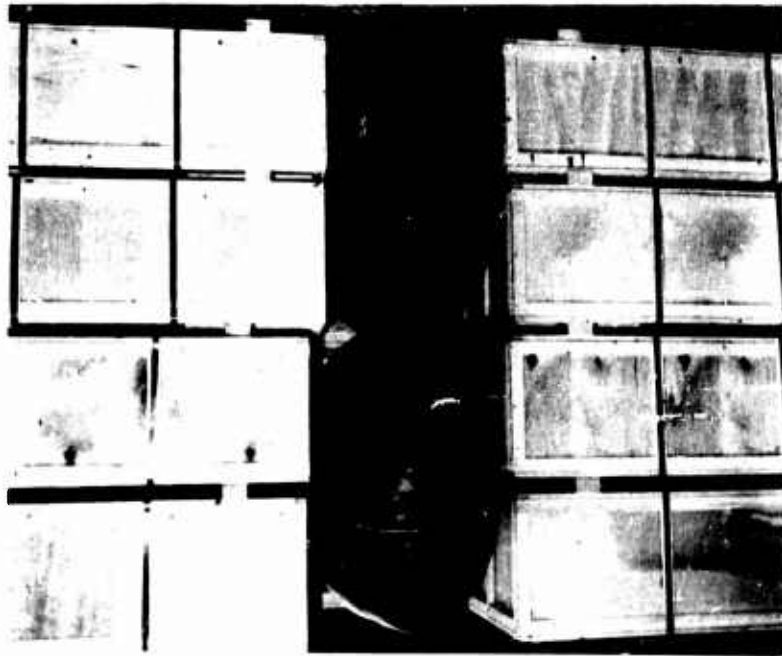


Fig. 6. Pneumatic dunnage.

The second use, of recent origin and one which has invoked a great deal of favorable comment, is pneumatic dunnage (Fig. 6) -- to protect military supplies from damage during rail shipments. These units reduce the time required in preparing freight cars for shipment, lessen the high labor and timber costs of present shoring methods, and reduce the damage caused by humping and shifting of loads during transit. In the production of these units a 13 oz nylon duck is used coated with 20 oz of coating on the outside and 9 oz on the inside to a total weight of around 42 oz/sq yd.

Future Potential Applications of Coated Fabrics in Army Uses. It will be apparent from what has been said that the field for application of coated fabrics in Army requirements is growing and, undoubtedly, will expand in the future due to the inherent advantage of lightness in weight combined with high strength. Also it will be apparent that the coating itself is simply one means of providing the desired property of water, weathering, or chemical resistance as the case may be. In other words, because high strength synthetic fibers can achieve such water resistance only by the use of coating at this time, this type of fabric is coming into these uses. It must be recognized, however, that in the continual effort to bring down weight and bulkiness of military equipment, the pressure will continue to be on increase strength of synthetic fibers to permit lightening of the weight, and on reduction of the amount of coating. It is entirely possible that fabrics having high strength and water and weather resistance will be developed in the near future utilizing far less coating than now or employing no coating at all.

Thus, during World War II while working on the two-man mountain tent we were concerned about having a coating on the nylon fabric to protect the nylon from ultra-violet deterioration due to the normal kind of exposure to which tents must be subjected. Today it would appear that this type of requirement for use of a

coating is passing out of the picture because the fiber producers are finding ways to increase the ultra-violet resistance of a fiber, as in the case of light-resistant nylon, or to produce fibers more suited for outdoor exposure than the nylon we had during World War II.

Similarly, it may be possible to achieve the desired degree of water resistance by processes other than conventional types of coating. One such approach might be to develop the equivalent of a very lightweight coating which would be internal within the fabric, would sufficiently close the interstices between yarns and filaments to provide essential protection, and be sufficiently resistant to outdoor exposure that such minimum amounts of material would have long term weathering characteristics. This might also be achieved by the development of a semipermeable type of coating, different from any which has been produced heretofore, which will permit water vapor transmission and still have a high degree of abrasion resistance and field durability. When one considers the impact of such fabric treatments as the precoating treatments presently in use in the industry today, it is not beyond possibility that extremely thin types of coating of high durability may be created which will completely change not only the present complexion of our coated fabrics systems but greatly widen the applicability of such fabrics. In all such approaches, however, it is our feeling that the study of fabric structure, the determination of optimum fabric geometry, and the proper employment of available and experimental fibers may create a different type of fabric for military uses than we are considering today.

Considering the types of fabric which have been used for coating to date, one cannot but be impressed with the rather pedestrian type of approach to fabric structure which has kept us closely allied to the concept of market availability or the use of fabrics already

developed for other purposes rather than the free exploration of fabric construction principles which have challenged textile technologists both in this country and abroad in other areas of textile fabric usage. To say that we are in an era of revolutionary change in textiles has become a trite expression. Yet, at times, one wonders if the implications of this transition stage are being considered fully from the standpoint of ultimate potentialities of known materials both in the field of fibers and in the general chemistry of application of coatings to textiles.

It is most important in a world situation such as we live in today -- in which we and our children are going to have to live for a long time to come, assuming that the Communists remain faithful to the Marxist dogma that the capitalist system will collapse without external help -- that we find ways to maintain a rate of technological progress which will assure provision to our Services of the most efficient equipment which the textile and coating industries can produce. That is our task in the Military Services -- rather it is our joint task: for you in the industry, and those of us who design military equipment, to provide the stimulus to our best minds in this field to assure such a rate of technological progress in this field.

Chairman Backer: Thank you, Dr. Kennedy for this interesting discussion of Army requirements for Fabrics for Coating.

The viewpoint of the military consumer is represented not only by the Army Quartermaster but also by a Naval Group as well as by representation from the Air Force. The next speaker represents the Philadelphia Shipyard and is in charge of the Textile Development Group at that yard, Mr. Robert Grubb.

NAVAL APPLICATIONS FOR COATED FABRICS

ROBERT GRUBB -- Graduated cum laude with a B. S. in Chemistry from St. Joseph's College in 1941. He has been on the staff of the Industrial Test Laboratory, Philadelphia Naval Shipyard for 17 years and currently is Head of the Textile Unit of the Development Section. He is the author of several papers on fire retardant materials and protective clothing for naval fire fighters and is co-author of one patent.

The design, operation, and functions of the ships of the United States Navy, are becoming increasingly complex with each launching or ship conversion. Naval architects continually are searching for improved methods of ship construction by incorporating the latest advances in science and technology into their designs. As the ships become more efficient and versatile, their operational requirements become more complicated, and as these functions become more specialized, the equipment required to operate the ships at maximum efficiency becomes more novel. Although most of the modifications refer to the armament, propulsion apparatus in the machinery spaces, hull structure, and the operational facilities; still there are a number of changes that have occurred, particularly among the types of auxiliary equipment with which the ships are outfitted, which involve the use of textile items.

During the period between World War I and World War II, the textile items employed aboard ships consisted almost entirely of the conventional hammocks and living quarter furnishings found within the ship, and the untreated cotton duck, bunting, and ropes found topside. Just prior to the start of World War II, fire-, water-, weather-, and mildew-resistant duck was substituted for the untreated cotton canvas and synthetic fibers were employed essentially for the manufacture of curtains of various types. At that time, however, there was little or no thought given to the development of lightweight fabrics for topside covers; to the manufacturer of the

various types of inflatable boats, rafts, and life preservers used today; to the design and fabrication of immersion suits, clothing, and equipment for our underwater demolition teams; to specialized protective clothing for fire fighters and those engaged in decontamination work; or to the development of fabrics for gun bucklers, berth covers, and fire-resistant artificial upholstery leather. Following World War II, the above development programs were initiated as rapidly as funds, equipment, and personnel became available; their need had been shown as a result of service experience. In each instance, the success of the project, either directly or to a great extent, rested on the development of suitable coated fabrics. Today, the Navy still is concerned with the development of lightweight coated materials for fabrication into lifesaving equipment. These items I would like to discuss in somewhat greater detail.

The Navy currently uses fire-, water-, weather-, and mildew-resistant canvas topside to cover lifeboats, guns, searchlights, hatches, cargo wells, and similar deck equipment. Also, considerable yardage of treated canvas is used in making deck awnings. Procurements of this material is from a list of "Qualified Suppliers", most of whom make use of the same general type impregnant which consists of an organic chloride (usually chlorinated paraffin), antimony oxide, an acid acceptor, mildew inhibitor, suitable pigments, and a resin binder. The add-on-weight due to treatment of an acceptable fabric is usually between 40 and 50%. Canvas impregnated in this manner performed well during World War II and is still being purchased because it does a satisfactory job at a reasonable price. According to the Federal Supply Stock Catalog, the cost per yard of treated canvas 42 inches wide is \$1.55. To illustrate the serviceability of treated No. 4 canvas, the Industrial Test Laboratory of the Philadelphia Naval Shipyard recently completed a series of outdoor weathering studies on a sample of treated canvas procured

from the normal production of one of the Navy's "Qualified" suppliers. The data presented in Table 1 show the properties of the fabric after exposure for one year at the United States Naval Research Laboratory, Tropical Exposure Site, Coco Solo, Canal Zone; at Cape May, New Jersey, a marine environment; and at the Philadelphia Naval Shipyard (Industrial Test Laboratory), an industrial site.

The disadvantages of impregnated canvas are essentially its weight, crockiness, difficulty in shedding ice, and its relatively dull, unattractive appearance. There is not much that can be done to overcome these objections; they are basic to the characteristics of a good, serviceable product. A lighter base fabric or the application of less compound could be employed to lighten the weight, but this also would result in a less durable cover. The resistance to crocking of the finish has been improved tremendously over the years, but handling of treated canvas usually still causes an objectionable color transfer to the hands and clothing. In cold climates, when the cotton fibers or the spaces between the threads become wet, not only will ice form which cannot be readily dislodged from the surface of the fabric, but the face itself can become so stiff and rigid that its handling is all but impossible. The appearance of treated canvas is not attractive initially and, in general, the treated canvas soils rapidly and fades -- dirt clings to its surface because of the tackiness of the finish. Treated canvas cannot be wiped clean but if cleaning is essential it must be laundered. This frequently adds to the faded appearance of the canvas and may decrease the efficiency of the impregnation.

Since even with these known defects treated canvas has performed well, it is logical to expect that any suitable canvas substitute must possess all of the essentially good properties of treated canvas, must eliminate some or all of the undesirable features of

TABLE 1

RESULTS OF TESTS OF #4 TREATED CANVAS EXPOSED OUTDOORS

Period of exposure (weeks)	Initial	52	52	52
Location of exposure racks	Roof (ITI)	Cape May, N.J.	sunlight	Panama jungle
Properties tested				
Visual biological determination	No apparent growth
Breaking strength, lb, warp	521	438	526	370
Water permeability, cc/10 min	0	0	0	1.5
Mildew resistance, mixed culture inoculation				
Visual growth	None	None	None	None
Strength retained after mildew attack, %	100	100	98	100
Fire Resistance	Warp Fill	Warp Fill	Warp Fill	Warp Fill
Flame time, max, sec	2.5 2.0	0.0 0.0	0.2 0.0	0.0 0.0
Flame time, ave, sec	0.5 0.5	0.0 0.0	0.1 0.0	0.0 0.0
Char length, ave, in.	0.2 0.2	1.3 1.0	0.9 0.7	1.2 0.9
				0.9 0.6

canvas without adding any new objectionable properties, and must remain competitive cost-wise. By cost-wise I do not necessarily mean the price per square yard but a cost-durability relationship. The question now arises: Are there coated fabrics which conform with these requirements and, if there are, how shall they be specified for procurement?

During the past year, particular interest has been shown by a number of naval shipyards in the use of vinyl-coated nylon fabrics for awnings, tarpaulins, and equipment covers. Several of these shipyards have initiated experimental installations of this type fabric aboard Fleet Units. In general, they report the following chief advantages gained through use of the fabric:

1. A lighter weight cover and consequently easier to handle.
2. A cover which can be stored wet without mildewing.
3. A waterproof cover.
4. A cover which is resistant to abrasion and attack by acids, alkali, oils, or stack gases.
5. A cover which is easily cleaned and repaired.
6. A cover which is durable in both marine and industrial environments.
7. The fabric is available in a wide range of attractive colors.

All of these properties are desirable in coated fabrics for naval use and it will be extremely interesting to observe how these trial installations perform as their period of serviceability is extended.

In view of the continuing need for lightweight coated material aboard ship, the Bureau of Ships has assigned the Industrial Test Laboratory of the Philadelphia Naval Shipyard the task of evaluating commercially-available lightweight coated fabrics to determine their suitability as canvas substitutes. Approximately 40 materials have been received for evaluation from various coaters. These have

included various weights of vinyl-coated nylon, including those brands being used by the various shipyards in their service installations, as well as neoprene-coated nylon, neoprene-coated Fortisan, vinyl-coated rayon, vinyl-coated cotton, and Hypalon-coated nylon. Tests to which these materials were subjected were the customary laboratory evaluations to which treated canvas would be subjected and included construction, breaking and tearing strength, fire- and mildew-resistance, water permeability, flexibility, heat aging, and accelerated weathering. In addition, these materials were exposed outdoors for one year at Coco Solo, Canal Zone; at Cape May, New Jersey; and at the Philadelphia Naval Shipyard. All tests have been completed on 22 samples; all but the exposures at Coco Solo have been completed on 13 additional materials. None of the vinyl- or neoprene-coated nylons in these groups is entirely satisfactory for use in place of treated canvas. All burned excessively. Following outdoor weathering, the strength retention of both type materials ranged from very good to very poor, apparently depending on both the formulation and the thickness of the coatings. It was noted that many of the vinyl coatings were stiff and boardy and the film had slightly separated from the base fabric of a few of the samples. Many of the neoprene-coated samples also became quite brittle, with the coating dusting or chipping and flaking off the base material. The Laboratory's accelerated weathering program, fortunately, also caused some delamination of the vinyl-coated materials whose film separated from the base material and therefore may serve as a suitable performance check on this property. Unfortunately, accelerated weathering did not cause flaking of the coating from those neoprene-coated nylons which weathered poorly outdoors. Figs. 1-3 illustrate some of the effects of weathering.

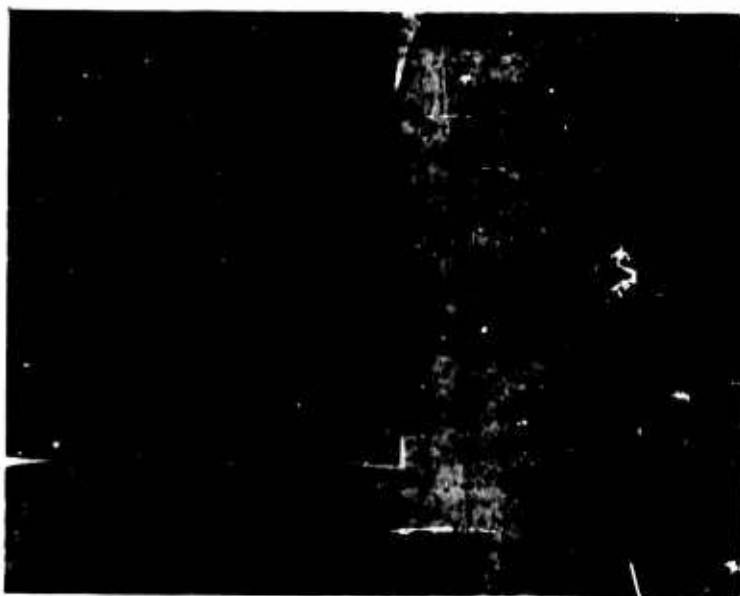


Fig. 1. Neoprene-coated Nylon following exposure at Cape May, N. J. for 6 months.

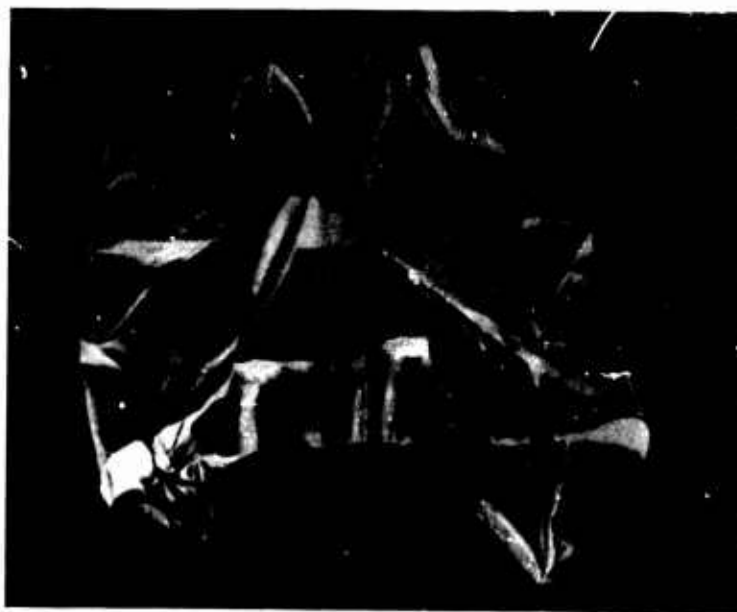


Fig. 2. Vinyl-coated Nylon following accelerated weathering.



Fig. 3. Vinyl-coated Nylon following accelerated weathering.

Tests also were completed on three neoprene-coated Fortisan materials and two vinyl-coated cotton ducks. The Fortisan samples were not durable when exposed outdoors. The performance of the vinyl-coated cotton fabrics was suitable in all respects but they weighed approximately 25 oz/sq yd, which is much heavier than desired. On the basis of the performance of the samples whose evaluation have been completed, the Department of the Navy has not yet found a suitable lightweight substitute for treated canvas. The investigation is continuing. Currently, several vinyl- and neoprene-coated nylons whose coatings have been specially formulated for fire resistance are on exposure. In addition, several extremely promising Hypalon-coated nylons and two vinyl-coated cotton ducks whose finished weights are 12 and 17 oz/sq yd respectively are being evaluated. It is hoped that one of these samples will perform suitably as a canvas substitute and that a satisfactory specification can be written covering its procurement. It still is not too late for participation in this investigation.

Samples or correspondence relating to this project should be addressed to the Development Section, Industrial Test Laboratory, Philadelphia Naval Shipyard.

The functional efficiency of lifesaving equipment also is a matter of vital concern to the Navy. Because of the limitations of weight and space aboard ship, this equipment is usually of an inflatable rather than a rigid construction. Naturally, this involves the use of coated fabrics. The plans and specifications for the Navy's inflatable lifeboats were prepared about 1945 but large scale procurement was not initiated until approximately 1950. This type boat made use of various weights of neoprene- and natural rubber-coated materials. As to be expected, many defects were found in the first models produced. Some were noted and corrected almost immediately, others became obvious only after service. For example, recently, while performing check inflation tests on boats currently in use, it was found that large blisters formed on the inflatable tubes at less than operational pressures. The "blistering" of these tubes preceded a rupture of the fabric and the consequent collapse of that portion of the boat. It was observed that the blisters were characterized by the complete or nearly complete degradation of the cotton base fabric and that the musty odor associated with mildew usually was prevalent. Subsequent tests indicated that actinic forces, acidic conditions from stack gases, and degradation of the neoprene coating had not appreciably influenced the extent of deterioration of the tube fabric, but that fungi was primarily responsible. The substitution of nylon for the cotton base material appears to have corrected this defect -- time will tell!

Other defects have not been so easy to overcome so that over the period of the last eight years the various design and material changes have increased the weight of the boat from 240 to 385 pounds. A piece of equipment which initially was difficult to

handle is now almost unmanageable because of its weight and bulk. One manufacturer claims to be able to reduce the boat's overall weight by 60 pounds without reducing its efficiency or performance. This is accomplished by the substitution of a newly-developed 15 oz neoprene-coated nylon for the 30 oz 9A type fabric specified in Military Specification MIL-C-17415. According to the exhibitor, the proposed fabric substantially conforms with all the present requirements for the heavier material. Laboratory tests have so well confirmed the manufacturer's claims that consideration is being given to the fabrication of an experimental boat using this new material. There are other opportunities for saving weight in the manufacture of these boats through the use of alternate materials for those presently specified. It is hoped that the coating industry will grasp this opportunity to assist the Navy in this development.

The fabrication of carbon dioxide inflatable life preservers for our underwater demolition teams from lightweight, uncured, double-coated fabrics also is a new development of interest. These jackets after assembly from the uncured stock are vulcanized in heated-pressure ovens. It is believed that this process will increase production and lower the cost when compared with the results of the current manufacturing technique in which precured, single-coated fabrics are assembled with cements which cure at ambient temperatures. Also, it should improve the jacket's gas retention and resistance to abrasion and result in stronger and more uniform seams. Thus far three small experimental lots of jackets have been produced using combinations of neoprene and Hypalon coatings with nylon and Dacron base fabrics. The efforts to produce preservers from Hypalon- and neoprene-coated Dacron were discontinued because of the relatively low tearing strength of the materials after vulcanization. Experiments with Hypalon-coated nylon also were stopped because of the low coating adhesion and the difficulty of handling lightweight

materials coated with a thin layer of Hypalon. However, several 11 oz and 12 oz neoprene-coated nylon materials have shown a great deal of promise and justify continuation of this program.

This discussion of Naval Applications for Coated Fabrics has referred to only a few of the textile problems with which the Bureau of Ships currently is confronted. The successful maintenance of the United States Fleet as the efficient operational force that it is today, to a great extent, depends on the continued support of industry in solving these problems as they arise. In the past, the textile industry and the textile coaters have been generous in their support of the various Naval programs for the development of improved textile items for shipboard use. This assistance is appreciated.

Chairman Backer: The role of coated fabrics in the Air Force will be discussed by Mr. Jack Ross. Mr. Ross is in charge of the Functional Textiles Section of the Textiles Branch, Materials Laboratory, Wright Air Development Center, Wright Patterson Air Force Base, Ohio. We have known Mr. Ross for some time and we know he will bring you an extremely interesting presentation of the views of the Air Force on requirements for coated fabrics.

THE ROLE OF COATED FABRICS IN TODAY'S AIR FORCE

JACK H. ROSS -- Graduated from Texas Technological College, having received a B. S. in Textile Engineering in 1948. Prior to working with the Air Force, he was in the Quality Control Laboratory of Borden Mills, Kingsport, Tennessee, handling quality control problems, laying out new fabric patterns, and evaluating textile equipment. Since 1951, he has been Chief of the Functional Textiles Section of the Textiles Branch, Materials Laboratory, Wright Air Development Center. In this position he has been responsible for parachute fabric and coated fabric research and development. Previous publications include "Changing Trends in Requirements for Parachute Materials", Dye&stuffs Reporter, July 1957.

The use of coated fabrics throughout the Military can be compared to a meteor in its rapid ascension. Since coating of fabrics was first conceived, military-type applications always come to the front primarily because of the protection from environmental conditions. Looking at the area which encompasses the Air Force, the use of dope-treated fabrics for aircraft surfaces appeared almost mandatory from the first aircraft flight. But today we're not interested in aircraft using dope-treated fabric surfaces. In this age of high speed aircraft, many uses exist for coated fabrics. Some of the present uses of coated fabrics on or in aircraft are wing covers, wheel well covers, engine covers, canopy covers, maintenance shelters, upholstery, floors, wainscoatings, headlining, aileron seals, thermal curtains, and heat duct shields. In clothing coated fabrics are used in fuel handlers suits, exposure suits, and pressure suits. Coated fabrics are also used in jet engine start up heat ducts, aircraft ground heating ducts, survival tents, life rafts, and life vests. It is apparent that a number of combinations of fibers with coating compounds are used. Most important of the fibers are cotton, nylon, and glass. In the area of coatings; vinyls, chloroprenes, natural rubber, silicones, and butyls are used to impart the desired protection. To discuss this entire field of uses and all of the needs for better materials could consume this entire conference. Accordingly, it becomes necessary to limit this discussion to some of the more important areas where coated fabrics play or should play an increasingly important role. In conjunction with this coverage I would like to spell out some of the more important requirements that exist for specific coated fabrics and those that exist for a general category of end items. Some of the unique or exotic type of requirements bear more consideration and study than the normal requirements of strength, weight, tear, and other factors. In discussing these various uses I will break them down

into the categories of shelters, aircraft covers, aircraft interior, clothing, and miscellaneous. A certain degree of relationship exists between the items in the first three categories; shelters, aircraft covers, and aircraft interior.

In the area of shelters used to protect engines and mechanics while making repairs in the field, the J-7 shelter is still standard where hangars are not feasible. Today we have changed from the vinyl-coated cotton to vinyl- or neoprene-coated nylon. Our specification MIL-C-20696 seems entirely adequate here. The nylon has eliminated the problem of mildew or fungi. In addition, greater resistance to wind damage can be obtained. This improvement in resistance to wind can be attributed to first Orlon and now Dacron sewing threads in conjunction with the coated nylon cloth. However, this type shelter is definitely fading out of use. The practice now is to utilize a portable or transportable metal hangar to cover the front part of the aircraft. Coated fabric will be used only around the protruding aircraft fuselage. Here again standard coated nylon is suitable. Therefore, in the area of maintenance shelters present materials are entirely satisfactory. The most important factor is the use of chloroprene coatings. This is based on outdoor weathering and artificial weathering tests that reveal greater protection is obtained from chloroprene than from an equal thickness of vinyl.

The area of protective covers for aircraft continues to be one where improvement of materials is necessary to fulfill the needs of the aircraft uses. There are four major components of aircraft which utilize covers. These are wings, engines, wheels, and transparent openings. Wings and transparent openings will be of concern to us today. The covers for engines and wheels -- other than changing to coated nylon (chloroprene mostly) -- have changed little, except in configuration. Wing and so-called canopy covers are of

considerable importance. Each of these covers have a definite place in todays combat aircraft. The wing cover of today is taking on considerable importance due to maintaining aircraft on combat alert. Since aircraft must be airborne in less than 15 minutes, a need exists for protective covers which can be jettisoned with minimum of effort. Although this is or could be a design problem, the fabric is still involved. An example of present day covers is shown in Fig. 1. Weight and strength still remain as key factors in the



Fig. 1. Wing and canopy protective covers.

material part of a wing cover. Another important factor is the ability to withstand short-term jet blast. Because of short alert time, it is conceivable that the covers would be exposed to jet blast as warm-up takes place. It is realized that a prolonged exposure to jet exhaust (even as short as 1/2 minute) could damage the fabric. However, some of the new plastic or elastomeric coatings might be applicable in this area. An improved fiber (with respect to heat) could also add to the overall cover useability under these conditions.

Covers for the protection of plastic canopies and of the equipment in the area under the canopies are of great interest. Weather and heat (due to sunlight) can damage the canopies or their attachments. Very definite damage can occur in a closed cockpit, while aircraft is parked, due to heat buildup. In many instances reports have shown that certain elastomers, plastics, etc., have melted. Instances where the shape of the canopies concentrated the sun's rays and actually started fires have been reported. To protect from these occurrences a cover is used (Fig. 2). This is a cotton twill,



Fig. 2. Pilot's enclosure cover.

napped on one side and coated with aluminized vinyl on the other. Of course, the nap is against the plastic. One very troublesome problem with this material, in the past, was the crazing of the canopy by the plasticizers which penetrated the cloth. With the replacement of Plex I and then Plex II -- as they were called -- in canopies, the difficulties with the vinyl and its plasticizer have disappeared. To a certain degree our efforts with new materials in this application has to do with reducing weight. Our present fabric weighs 14 to 16 oz/sq yd -- a very heavy, bulky cover when we consider some of the canopy areas of new aircraft. One cooperative

Coater has devoted some time to the development of a napped and coated nylon fabric. Considerable effort along this approach will be needed to obtain a suitable replacement for the present item. There is every reason to believe that a 7 to 9 oz/sq yd vinyl on nylon fabric can be developed with sufficient nap to protect the aircraft's plastic windows.

Having talked about covers on the outside of the aircraft, we will now consider the "innards of the beast". Here the use of coated fabrics is almost unlimited. In transport and combat crafts we find innumerable coated fabric uses. A few are upholstery, floor covering, headlining and wainscoting, curtains, seals, bunk

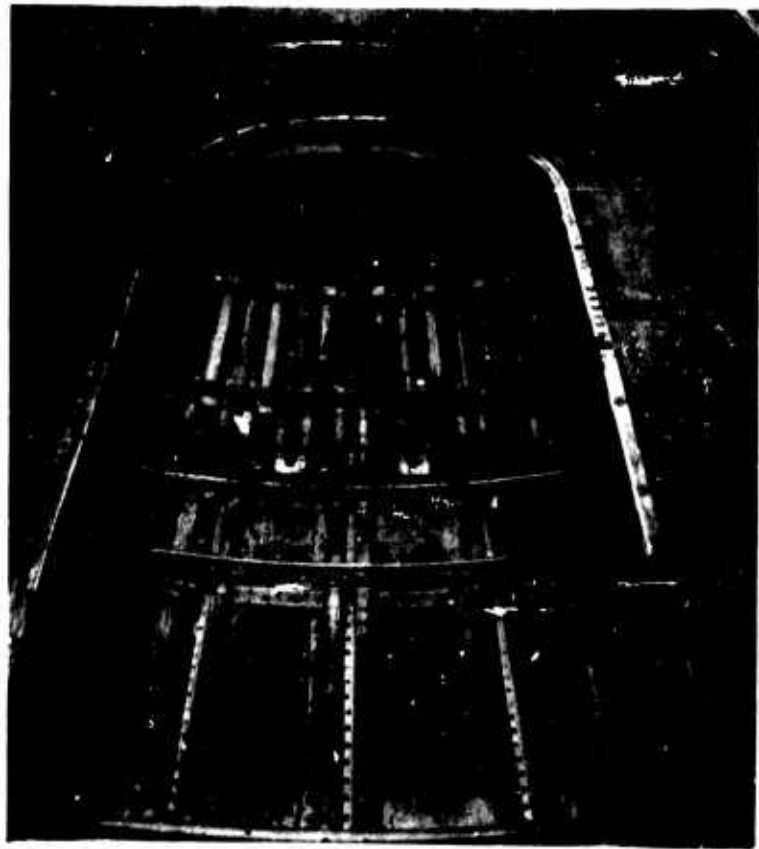


Fig. 3. Corrosion - lounge floor area of an aircraft.

covers, and refueling boom operators pads. In this large field, let's consider two uses. In Fig. 3 corrosion can be seen on the "belly" of an aircraft. During the aircraft's descent from altitude water, due to condensation, accumulated because the coated fabric over the insulation was not only waterproof, but water-vapor proof. The water vapor could not pass through. Trapped, it condensed and eventually worked down to a spot where a leak allowed a pool to gather; corrosion resulted. In our aircraft, thermal and accoustical insulation is obtained by having the following layers:

1. Coated fabric.
2. Fiberglas batting.
3. Cotton or nylon scrim (optional).
4. Vapor Barrier.

If the coated fabric is effective in preventing water vapor to escape, condensation occurs and corrosion could follow. This corrosion can also result if the vapor barrier fails. In some applications a coated fabric replaces the vapor barrier (Figs. 4 and 5, blanket installations).

Many years ago, these blankets were quilted. Today, since good, long-lasting adhesives are available, a cemented structure is used. Light weight, excellent tear strength, and flame resistance are required. We are satisfied with a coated fabric which will pass the vertical flame test as described in CCC-T-191b, with a maximum of two seconds flame time and three seconds glow time. Of course we must remember, the fabric coating cannot promote corrosion. Let me add another, and to a degree, new requirement. We know that Mylar and Polyethylene, which are vapor barriers, fail at low temperatures. Most of our coatings can't take much over 450°F. Today, we are interested in temperatures of 700°F resulting from aerodynamics friction on the aircraft skin. Even higher temperatures can exist. For this information we have to

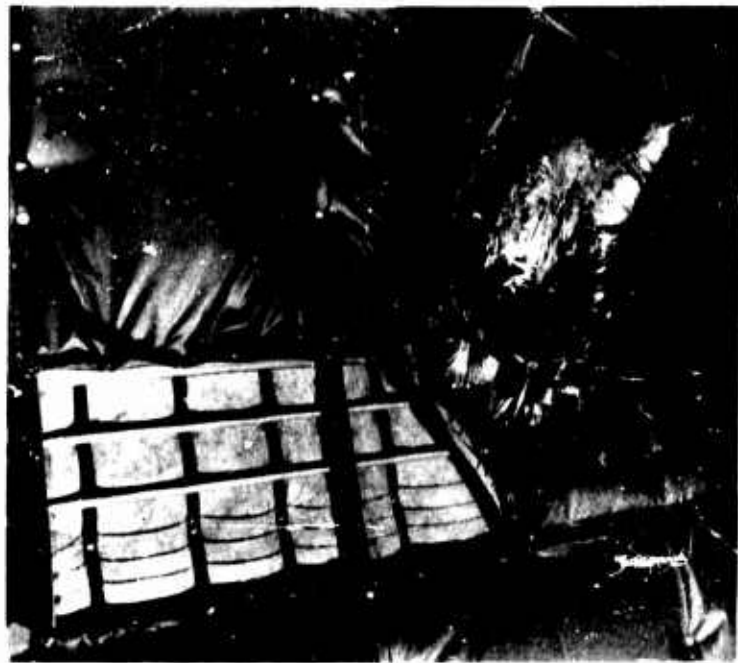


Fig. 4. Blanket installation.

wait for actual data from flight-tests of the newer aircraft. It is obvious that the present vapor barrier materials will have to be replaced. Coatings will have to withstand temperatures of 700°F for periods of 10 to 30 seconds. The basic fabric will have to be just as resistant to heat as the coating. In this application the weight will be very important. Weights of less than 3 oz/sq yd for the coated fabric will be a very important must. Strength will not be of concern since the coated fabric will be against the aircraft skin.

Changing the subject, let us look at an area where coated fabrics might not be used in the future. This is the seat covers for aircraft in which the pilot cannot get up and move around to keep the "seat" from getting sore. To prevent formation of sores and to prevent interruption of blood circulation, knitted fabrics are being used as cushion covers. Actually, the fabric is placed in a mold and the ingredients to form a foam are added. The resulting cushion

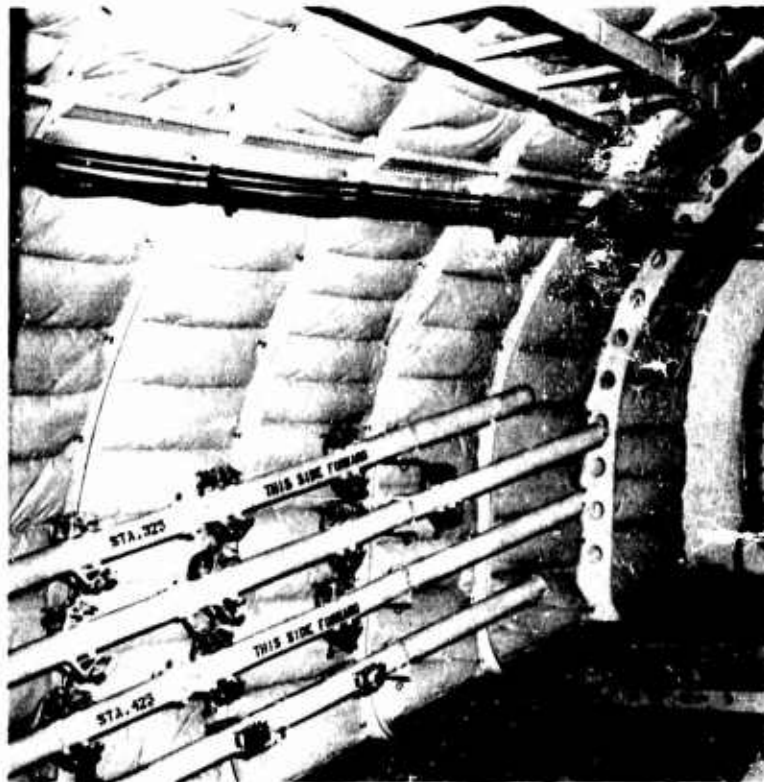


Fig. 5. Blanket installation.

will stretch at those points where the pressure is applied (primary loading occurs where the two bones come closest to the surface of the man's "rear" when sitting). The pilots who have utilized these cushions, in almost all cases, refuse to return them -- a sure sign of achieving the desired goal. Actually the knitted fabric was the critical item. Equal stretch in all directions was required. Through the use of stretch nylon and knitting, a satisfactory fabric was achieved. This is a specialized application.

An important area in the use of coated fabrics in aircraft concerns protection of the crew from high intensity thermal burns or blindness and prevention of damage to equipment (Fig. 6). A great deal of work has been done in the evaluation of materials when

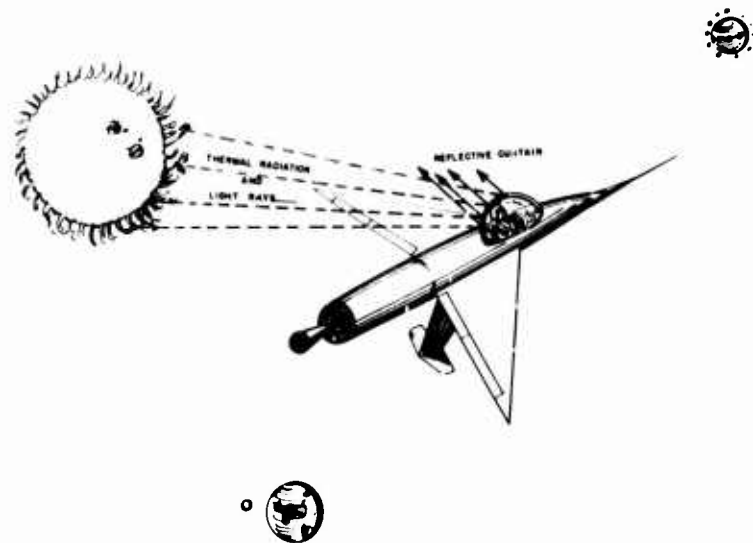


Fig. 6. Coated fabric reflective curtain for crew protection.

exposed to thermal sources. The use of high intensity carbon arcs has made this evaluation possible. We must protect our aircrew from various degrees of thermal intensity. Specifically, I cannot talk about these, as they are classified. However, some information has been published as to the amount of heat in cal/sq cm that man can take. It is small compared to what the aircraft can take, but of necessity, the man must be protected. Until recently we relied on bleached cotton duck to achieve protection. However, we are faced with a problem of intense light as a compounding factor. The duck will transmit about 3% of this light; too much, as far as the pilot is concerned. Data have been obtained which show 1.5% light transmission at these high intensities is a maximum. This brings us to a coated fabric, one which can take heat at very high flux levels for fairly short periods. Silicone rubber on glass fabric appears satisfactory with respect to the thermal aspect. However, the silicone must be white. This results in a fairly opaque fabric which, as we have now, must be heavy (about 20 oz/sq yd) to prevent light transmission. Inasmuch as weight is a

problem in aircraft, even ounces can be of concern. So when we're asked to reduce the weight of this fabric by 50%, the question of retaining primarily the low light transmission is raised. This is where we stand now. What fabric we use will depend a lot on the ability of industry to arrive at some new concepts in elastomers and means to reflect light and provide thermal protection.

I would like to talk a little about the clothing area: what the Air Force is looking at in fulfilling requirements for coated fabrics for pressure suits, fuel handlers suits, and exposure suits. The fully equipped pilot of today looks in a sense like a deep sea diver. He is heavily weighted down by various flight garments, each having a specific use and very definitely required for safety. We must through fabric and coating development obtain lighter and less bulky coated fabrics. The present outer garment is the exposure suit. The fabric is a nylon oxford (MIL-C-508) coated on one side with chloroprene. Strength is a consideration because a minimum hydrostatic water resistance of 175 psi is required. Flexibility without cracking of the coating at -67°F and non-tackiness at 170°F are additional requirements. A maximum finished weight of 11 oz/sq yd results in bulkiness. Of very great concern to the Aero Medical people of the Air Force is the pressure suit intended for protecting pilots at the proposed very high flight altitudes. One of the prototype suits is shown in Fig. 7. The pressure suit is not standardized to the point that materials specifications have been prepared. Each contractor has been allowed to choose the specific materials for use in the suit. The basic fabrics have been restricted to nylon and Dacron in order to conform to seam strength and weight requirements.

With respect to seam strength, the following three sets of requirements exist: Fabric I, 200 lb in the warp and filling; Fabric II, 100 lb in the warp and filling; and Fabric III, 200 lb in the warp



Fig. 7. Prototype pressure suit for high altitudes.

and 100 lb in the filling. This is per inch of width and type of seam is optional. A maximum weight of 10 oz/sq yd for base fabric and 15 oz/sq yd for the coated fabric has been established. In addition, a pressure vessel made of the fabric must hold 10 psi for a minimum of 24 hours. The coating compound has been limited to the chloroprenes because of its superior ozone resistance. We can see that a fertile field exists here for improvement through coating compounds and/or through fabric construction.

The last clothing material area I will cover is that of the fuel handler suit fabric. A great deal of development has been accomplished by the three services. The material most used, it appears, is the

polyvinyl-coated Fiberglas covered by Specification MIL-C-12526A. The suit is not stocked by the Air Force, but it is known to be bought as a commercial item by Air Force groups. Another material, a butyl-coated item, resists red fuming nitric acid vapor penetration for more than 6 but less than 24 hours while resisting red fuming

nitric acid liquid penetration for more than 24 hours. This coating does swell somewhat when exposed to gasoline. No effect is noted when exposed for one hour to such rocket fuels as H_2O_2 (90%), hydrazine, and ethyl alcohol. This item has been found to be very good by the three services. A final material, not in general use but one that has been service tested, is a polyethylene-polyisobutylene-coated cotton fabric. It is superior to the butyl-coated material with respect to rocket fuel and oxidizer resistance. The major deficiency of this coating is that JP-4 fuel (used in jets and some rockets) severely discolors and damages it after three minutes immersion. These three coatings are not considered satisfactory for imparting resistance to high energy fuels (HEF) now being developed for jet and possibly rocket engines. Although HEF-2, the most volatile of HEF types, will never be an operational fuel; it is the most suitable for use in screening the materials developed, because it is the most difficult to handle.

The basic requirement for a protective material is that it shall be impermeable to HEF-2 for 24 hours. A sensitivity of better than one part per million of HEF-2 is a must in any screening test. Any coating used must be resistant to swelling or other dimensional changes over a similar 24 hour period. In addition, compatibility of the coating with such decontaminating agents as alcohol and ammonia water is necessary. Flexibility through a temperature range of -40 to $140^{\circ}F$ without cracking or tackiness is an additional requirement. Of course, if a coating were developed which could meet these requirements and be resistant to the present liquid rocket fuels, an ideal multiple-purpose suit could be used in many applications. In leaving this area, I might note that our Protective Clothing Materials Section has conducted sufficient studies to believe that fluorinated type elastomers would be a likely compound for coating. Such fibers as cotton, dacron, or glass could be used in a base fabric.

The other miscellaneous material is that of hoses used for the movement of hot air to jet engines during ground start-ups. Air at pressures as high as 400 psi and at temperatures of 400 to 600°F from a gas turbine source is fed to the engine. The hose is normally made by lining woven Dacron hose with a silicone rubber liner and curing the rubber while on a mandrel to effect adhesion of the rubber to the hosing. One problem area recently solved was the failure of hose due to kinking. This failure was attributed to heat damage and pressure build-up at the location of a kink. The failures were due to the inability of the warp yarns to flex properly when the hose was bent while under pressure and heat stress. Studies showed that by using a braided structure the geometric pattern was such as to eliminate kinks. Proper yarn size and ply had to be considered to prevent the silicone rubber from blowing out through the interstices of the braid. Further, we might note that silicone rubber, being fairly porous, does not give adequate protection to the Dacron hosing. So basically, a new high-temperature fiber is required unless a dense, high-temperature elastomer can be found to afford more protection to the present Dacron yarns.

In summarizing the various areas that have been covered, I believe the following general statements will indicate a trend in requirements for coated fabrics:

1. Base fibers with temperature resistance above that of nylon and Dacron.
2. Base fibers with a lower specific gravity while maintaining the strength of present nylon.
3. Of some concern are a need for fibers with greater ultra-violet light resistance to increase coated fabric life.
4. Elastomers or plastics with high-temperature resistance.
5. Elastomers or plastics with a greater density to prevent heat diffusion to base fabrics.

In the realm of specific requirements, our first and foremost one is for a coating material to resist high energy fuels. The requirement of impermeability for 24 hours is one dictated by the toxic nature of the fuel. Temperature-wise, fibers that will withstand 500°F while retaining 50% strength are necessary for use in thermal curtains and hot air ducts. Elastomers or plastics which will withstand temperatures of 700°F are needed for coating on a high-temperature fiber. For thermal and accoustical blankets; low cost, high-strength fibers and coatings are needed to maintain an overall low weight installation.

In closing, it is necessary to point out that in most cases the Air Force Development budget is such as to preclude projects on coated fabrics other than in clothing items. We in the Air Force appreciate the time, materials, and effort spent by the coated fabrics industry in the preparation of experimental elastomers and plastics applied to various fabric construction.

Chairman Backer: The next speaker is Dr. Austin Henschel, Head of the Environmental Protection Division of the Quartermaster Research and Engineering Command. He represents, you might say, the last batter up in the inning devoted to consumer needs in the field of coated fabrics.

DESIGN FOR CLIMATIC EXTREMES

AUSTIN HENSCHEL -- Attended the University of Minnesota where he received a B. S. in Zoology, a M. A. in Histology, and a Ph.D. in Physiology. He came to the Quartermaster Research and Engineering Command in 1951 from the School of Public Health of the University of Minnesota where as Associate Professor of Physiology, he conducted research on the effects of nutritional status, the environment and work on the capabilities of man. He is presently Chief, Environmental Protection Research Division, Quartermaster Research and Engineering Command.

This paper will be concerned with only two of the many problems of military applications of fabrics for coating. My remarks will be limited to a discussion of the extremes of climatic environment in which the fabrics may be used or stored and the physiological problems of maintenance of body heat balance when wearing coated fabrics.

Any fabric, coated or non-coated, placed on the skin of the man forms a barrier to the free exchange of heat and moisture between the man and the environment. The degree to which a fabric acts as a barrier depends upon the functional properties of the fabric -- air, heat, and moisture permeability -- and, of course, is unrelated to the structural characteristics. In any event, the fabric system alters the rate of heat and moisture gain from or loss to the environment. This interference with the normal free heat exchange may be either an advantage or a disadvantage to the man. This again depends upon a number of interrelated factors.

In order to remain operationally effective, the soldier, as well as all warm-blooded animals, must keep his body temperature within a rather narrow limit. Man has been able to survive in air temperatures as low as -105°F for hours in the Antarctic and as high as 250°F for 1/2 hour in laboratory studies. But even in these extreme environments, the body temperature was maintained between 95 to 104°F . Exceeding these temperatures for even relatively short periods of time will lead to trouble and eventually to death. Anything then that may interfere with the ease of achieving this constancy of internal body temperature must not be overlooked.

What are the factors that are important in determining heat balance? The internal physiological mechanism and processes will be assumed to exist and will not be considered here. Net heat gain or loss depends upon the following relationships:

$$\text{Heat Balance} = M - E \pm R \pm C$$

M = Metabolism or energy production by the body.

It may range from 50 at rest to 1000 Cal/hr for extremely hard work that can be continued for only relatively short periods. A 20-fold increase in metabolic heat production is possible.

E = Evaporation of water (sweat) from the skin. From 20 at rest in a neutral environment to 100 Cal/hr in a hot environment when sweating to maximal -- may be lost this way.

R = Radiation both from solar and long-wave sources. Up to 250 Cal/hr may be gained from the sun during the middle of the day. Heat may be gained or lost by long-wave radiation depending on temperature differences between the skin and the surrounding objects including space. From long-wave radiation 100 Cal/hr may be lost or gained.

C = Conductive and convective heat gain or loss.

There are a number of modifying factors that must also be considered. These include wind, humidity, and clothing.

Wind influences rate of heat gain or loss by influencing the rate of evaporating and of the heat gain or loss by conduction and convection. This influence of wind on heat loss is especially well documented for the cold. The windchill concept expresses the wind-air-temperature-cooling rate relationships. Temperature-wind speed relationships that will result in a 1400 Cal/m²/hr (m = meter) heat loss from exposed skin are as follows:

<u>Wind (mph)</u>	<u>Temperature (°F)</u>
45	20
18	10
13	0
7	-10
5	-20
3	-30
2	-40

Exposed skin freezes within a few minutes at a windchill of 1400. A windchill of 2500 approaches the maximum cooling rate recorded under natural conditions. A windchill of 200 is pleasant, one of 800 is cold. Windchill maps of the world have been made along with maps illustrating ability of man to accomplish useful work while exposed.

Clothing or body covering decreases the rate of heat gain from or heat loss to an environment. Clothing then is an advantage under conditions where heat conservation is needed and a disadvantage when heat loss is required. The degree to which clothing alters heat gain or loss depends upon many factors -- fiber and fabric structure, design and thickness, air and vapor permeability, level of metabolism, and environment. For example, heat loss by conduction and convection through a 4 clo clothing ensemble (winter wear) would be 20 Cal/hr at 98°F, 77 Cal/hr at 32°F, 124 Cal/hr at 0°F, 124 Cal/hr at -20°F, 174 Cal/hr at -40°F, and 199 Cal/hr at -55°F.

Humidity alters evaporation rate - when vapor pressure is low skin moisture evaporates more readily and heat loss is increased; when vapor pressure is high, rate of heat loss by evaporation is slowed.

Coated fabrics in the cold may decrease heat loss by evaporation during hard physical work and they may interfere with body movements in extreme cold if they stiffen or become hard.

In hot environments, coated fabrics may cause serious physiological problems by interfering with sweat evaporation and air movement next to the skin. Sweat evaporation in the heat is the major, or in some situations, the only means of maintaining body heat balance. Also, a continuously wet skin may lead to skin disorders as was experienced in World War II in the Pacific. A man doing moderately hard physical work in the sun with air temperatures of 110°F but with relatively low vapor pressure characteristics

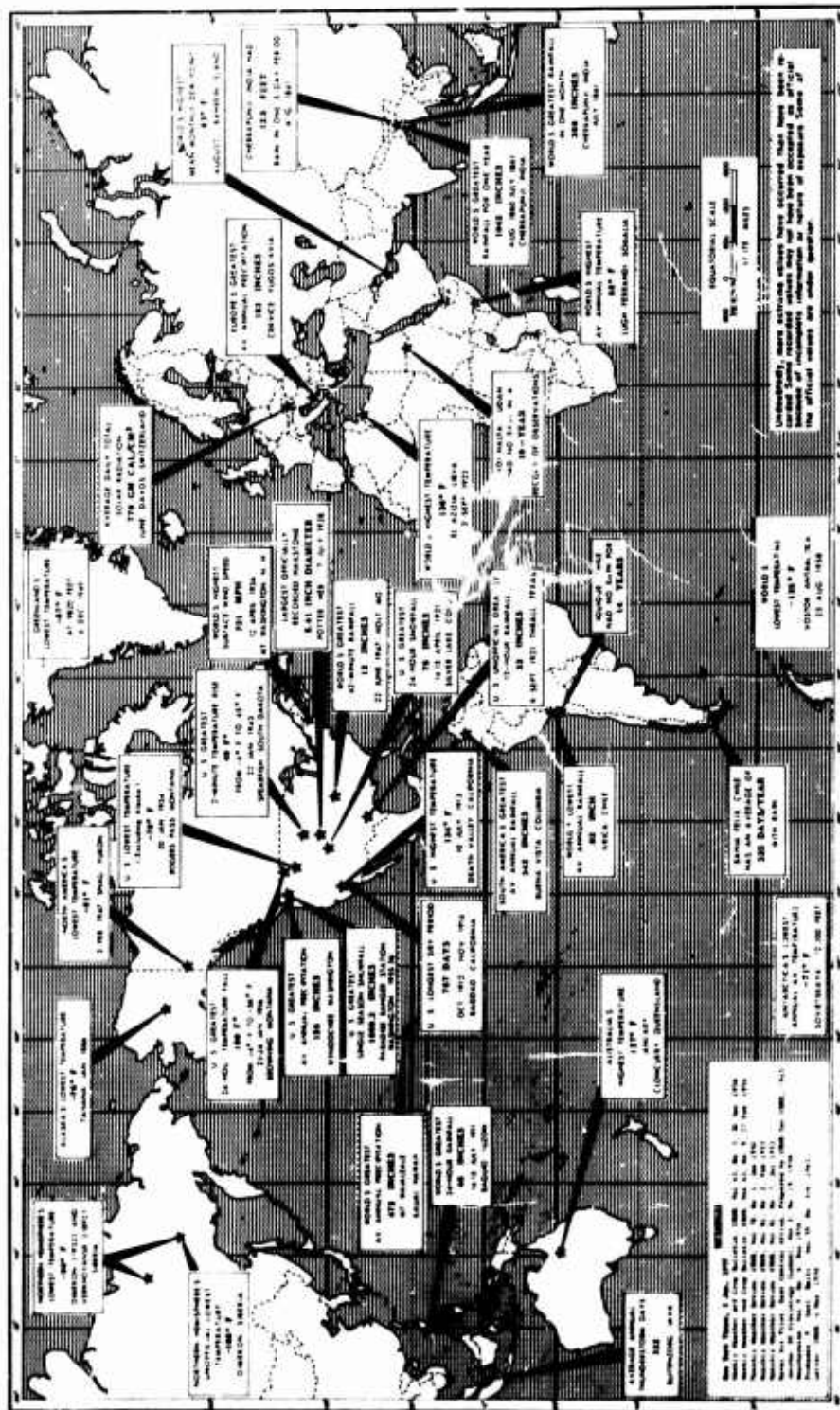


Fig. 1. Weather extremes around the world.

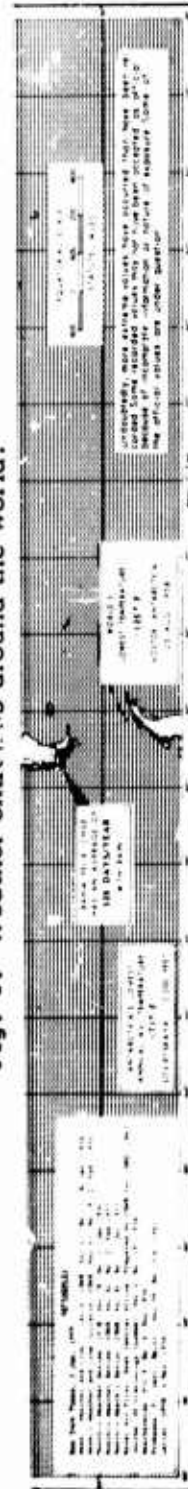


Fig. 1. Weather extremes around the world.

of the summer deserts of the Middle East would have to sweat and evaporate about 1.2 liters (3 pints) of sweat per hour. Interference with the evaporative process could rapidly be disastrous to the abilities of the soldier to do his work.

Let us now briefly review the extremes of climatic factors which coated fabrics and other material may be exposed to during use or storage. Military standard 210A, 2 August 1957, "Climatic Extremes for Military Equipment" and AR 705-15 dated 14 August 1957, "Operation of Material Under Extreme Conditions of Environment" set forth the probably climatic conditions to which military equipment may be exposed during use, transit or storage under operating conditions, extreme cold weather, and extreme heat conditions. Table 1 summarizes some of the information presented in Military Standard 210A and AR 705-15.

TABLE 1
SUMMARY OF MILITARY STANDARD 210A AND AR 705-15

<u>Env. Factor</u>	<u>Basic</u>	<u>Cold</u>	<u>Hot</u>
Temperatures	-25 to 115°F	-65°F	125°F
Humidity	5% at 115°F 100% at -25°F 95% at 80-85°F 100% below 80°F	NA	As low as possible At 125°F
Rainfall	12 ins. in 12 hr 7 ins. in 1 hr	NA	As basic
Wind	80 mph with gusts to 120 mph	As basic	As basic
Storage capabilities	-65 to 155°F		

Other factors such as atmospheric pressure, blowing sand and dust, and snowload are also included. Of course, the extremes used in Military Standard 210A and AR 705-15 do not occur all the time, but more extreme conditions do occur on occasion. For practical purposes, more important than absolute extreme climatic factors is duration and frequency of occurrence.

of the summer deserts of the Middle East would have to secrete and evaporate about 1.2 liters (3 pints) of sweat per hour. Any interference with the evaporative process could rapidly become disastrous to the abilities of the soldier to do his work.

Let us now briefly review the extremes of climatic factors to which coated fabrics and other material may be exposed during use or storage. Military standard 210A, 2 August 1957, "Climatic Extremes for Military Equipment" and AR 705-15 dated 14 August 1957, "Operation of Material Under Extreme Conditions of Environment" set forth the probably climatic conditions to which military equipment may be exposed during use, transit or storage under basic operating conditions, extreme cold weather, and extreme hot conditions. Table 1 summarizes some of the information presented in Military Standard 210A and AR 705-15.

TABLE 1
SUMMARY OF MILITARY STANDARD 210A AND AR 705-15

<u>Env. Factor</u>	<u>Basic</u>	<u>Cold</u>	<u>Hot</u>
Temperatures	-25 to 115°F	-65°F	125°F
Humidity	5% at 115°F 100% at -25°F 95% at 80-85°F 100% below 80°F	NA	As low as 5% At 125°F
Rainfall	12 ins. in 12 hr 7 ins. in 1 hr	NA	As basic
Wind	80 mph with gusts to 120 mph	As basic	As basic
Storage capabilities	-65 to 155°F		

Other factors such as atmospheric pressure, blowing snow, sand and dust, and snowload are also included. Of course, the extremes used in Military Standard 210A and AR 705-15 do not occur all the time, but more extreme conditions do occur on occasion. For practical purposes, more important than absolute extremes of climatic factors is duration and frequency of occurrence. Data on

a world-wide basis are being analyzed with this in view, particularly for low temperatures. Derivation of frequency of occurrence of high temperatures for some of the "hot" regions of the world is underway. When these data become available, they will provide a more functionally realistic basis for setting environmental design criteria. Similar data will be generated and guidance criteria developed for the other environmental factors such as humidity, wind, rain, snow, and dust.

In considering any fabric for coating, among the many problems that must be kept in mind are the useability and storage characteristics of the material under the extreme environments and the physiological problems that utilizing such materials by the soldier might create.

Chairman Backer: I'd like to present our next speaker, Dr. M. M. Platt, Fabric Research Laboratories of Dedham, Massachusetts. Dr. Platt is a civil engineer by education who became interested in textile research early in the 1940's and, since that time, has contributed significantly to our knowledge of engineering analysis in the field of textile structure. We are, therefore, happy that Dr. Platt is able to join us to discuss the Interaction of Fabric Structure and Coating Type as Affecting Performance.

INTERACTIONS OF FABRICS AND COATINGS

MILTON M. PLATT -- Graduated from Massachusetts Institute of Technology in 1942 with a B.S. in Building, Engineering and Construction, and received a Sc.D. in Civil Engineering in 1946. Dr. Platt has been associated with the Fabrics Research Laboratories, Inc. since 1946, and is presently Associate Director. He is a member of various Textile Societies, a member of the Society of Rheology, and an Honorary Life Member of the Lowell Technological Institute Engineering Society. Dr. Platt has written numerous articles pertaining to textiles, many of which have appeared in the Textile Research Journal.

Those of us who are involved in textile research have witnessed a remarkable phenomenon in the past decade. More so than at any other time in history, the problems associated with the creation, production and practical utilization of textiles have been attacked by application of a growing background of science and technology. The vastly improved functional performance of fabrics with which we are all familiar in our everyday lives brings sharply into focus the successful industrial utilization of this technical background. Without the courage of the various governmental and industrial agencies which supported pioneering research in this complex field, without the painstaking and oftentimes frustrated activities of many dedicated research workers, and without the large number of farsighted applications by the American businessman attempting to utilize frequently incomplete research results, the great variety of apparel and industrial fabrics from which we can today choose to satisfy our needs would doubtless not have been available.

When I was asked to prepare a paper on interactions of fabrics and coatings, I was particularly enthusiastic because here was a field of utilization which involved many technical disciplines -- that of the chemist with respect to chemical structure and properties of coating materials, that of the coater with respect to how coatings are applied, and, finally, that of the textile engineer or technologist who would be aware of the properties of fabrics and their dependence upon fiber type and fabric construction. A closer study of the problem of preparing this paper left me somewhat less enthusiastic. In the first place, I am not a chemist, and not only am I unfamiliar with the structure of coatings, but oftentimes with their names as well. Secondly, I am not a coater, and aside from some rather elementary implications of the effects of methods of coatings which I will subsequently discuss, I know nothing about practical methods of applying coatings. Moreover, and notwithstanding its obvious importance, as indicated by the need for

this meeting, I am sorry to say that there is very little of a specific quantitative nature on fabric-coating interactions which I can report to you. This, I take it, is the result of the extremely minor amount of research which has been performed on the subject, since the literature seems quite devoid of pertinent information of a specific nature.

From the foregoing, you are in a position to question what special qualifications I possess or how I can contribute to this conference. I think it lies mainly in pointing out some of the future work which must be done in order to answer the question: How do fabrics and coatings interact? This I intend to do by delineating as simply as possible 1. Some of the basic mechanisms involved in the reaction of uncoated fabrics to a selected externally applied stress; namely, tear, 2. the influences of fiber properties and fabric structure on response to this type of stress, and 3. inferences as to how coatings could influence this "natural" response. By doing so, I am certain that more questions will be raised than will be answered, but these I hope may serve to set some of the goals of future research in the field of coated fabrics.

Coatings are applied to textile fabrics for a variety of reasons, usually to protect the fabric (or the wearer in the case of apparel use) against the elements of contact wear or abrasion, atmospheric degrading influences such as ultra-violet radiation, water or gas penetration, and others. From the point of view of satisfying many if not most of these protective considerations, most coated fabrics respond very nicely to their service use. The items which I will discuss are those which in many cases are, or can be, harmful to a requisite mechanical property of a fabric because of the presence and properties of a coating; in other words, because of interaction.

Tear resistance has been selected as the major mechanical property to be considered -- firstly, because of its importance as

a property of coated fabrics; secondly, because it is very sensitive to interaction; and lastly, because there is more technical background on this subject than most. Let us begin with a general, simplified discussion of what contributes to tear strength of base fabrics, and for definiteness we will consider a specific means of evaluating tear; namely, the tongue tear test. A more complete analysis than that presented here may be found in the work of Teixeira, Platt, and Hamburger (1). Past salvage studies of field garments by the Office of The Quartermaster General showed that tear strength was a prime consideration in the life of raincoats and ponchos, and that a preponderance of service tears were analyzable as tongue-type tears. From a scientific point of view, the work of Krook and Fox (2) on the mechanics of tear was a notable pioneering achievement. Through analysis and observation, they discerned that the mode of failure involved in tearing of woven fabrics was a tensile rupture of the yarns being torn, in contrast to previous thinking on the matter which considered tear to represent a shear phenomenon. Diagrammatically the situation, as basically elucidated by Krook and Fox, is shown in Fig. 1, which I will describe, because the mechanism involved is basic to the discussion.

As load is applied to the fabric, by motion of the jaws into which the tails are clamped, a gross distortion of the fabric geometry takes place locally in the active region of tear, the so-called "del". From an overall point of view, those threads originally at right angles to the direction of subsequent tear attempt to orient themselves, as the load is increased, in a direction parallel to the tear, while the opposite system of threads also attempts to undergo a 90° rotation. This gross directional distortion takes place chiefly over a very restricted area, since substantially all of the force created by the jaw motion is

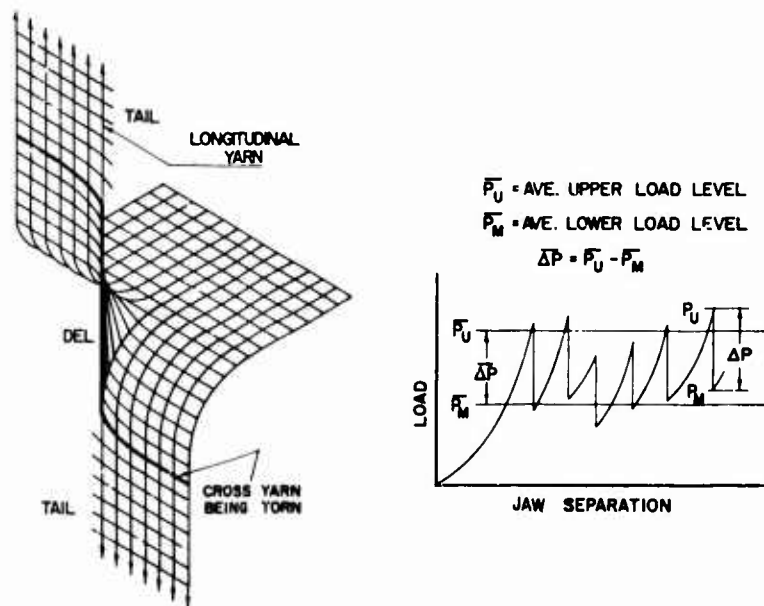


Fig. 1. Tongue Tear Test.

transmitted from one tail to the other tail by way of the del. As the external load is increased further thereby increasing stress, strain is applied to the originally transverse yarns until one or more of the most highly strained of these in the del ruptures in tension, and a load-drop takes place. Neglecting certain complex elastic interactions which occur almost simultaneously with the load-drop, a lower level of load is attained which, to a first approximation, represents the load being carried by those strained del yarns still intact. Subsequent increases in external load produce repetitions of the action described, with upper load peaks representing points of failure and lower load peaks representing the more or less steady state supportive force. Clearly then, total load-carrying capacity, to the point where a thread ruptures, is dependent upon 1. yarn tensile strength, 2. the number of yarns in the del supporting the applied load, and 3. the uniformity of the loads being borne by the yarns.

Regarding yarn tensile strength, the unusual feature of interest is that tensile strength corresponding to a very low gage length is meaningful here, since the "effective" gage length of the yarns is quite small during a tear, of the order of a small number of longitudinal thread spacings. This factor is significant when considering either very low twist spun yarns or single yarns generally, where strength rises rapidly with decreases in gage length at low gage lengths.

Yarn tensile properties, other than tensile strength, contribute to tear strength, shape of the stress-strain curve, and magnitude of elongation to break. The tensile strain to which the originally transverse yarns now in the del are subjected diminishes from the outside edge to the untorn section of the fabric. Loads will be borne by these threads corresponding to the stress-strain curve shape. Obviously, a yarn which exhibits a high percent of its ultimate breaking stress over a broad range of strains will contribute more load-carrying capacity than would one which showed a high dependency of stress on strain. The effect on tear of stress-strain curve shape is illustrated in Fig. 2. Here are shown two different stress-strain curves, both however, possessing identical end points. Curve A shows high load support over a broad range of strains, while for B there is a high dependency of load on strain. The vertical lines represent strain distribution amongst adjacent del yarns, assumed alike for both yarn types. Total load-carrying capacity of the del at thread rupture, in either case, is given by the sum of ordinates to the respective curve. Clearly, total tear load will be greater for fabrics made of Yarn A than for those made of Yarn B. Elongation to break is significant since it is clear that the more the strain to which the most highly stressed elements can be subjected prior to failure, the greater the total number of del yarns which can contribute load to resist the tear prior to yarn rupture.

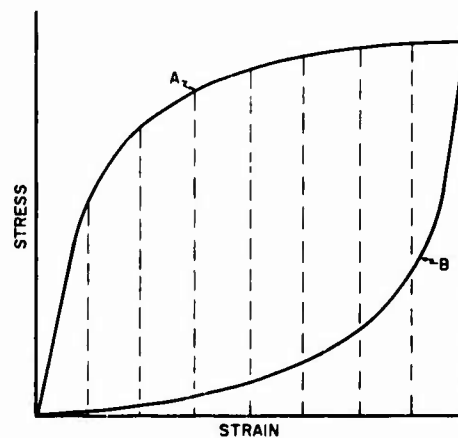


Fig. 2. Illustration of effect of shape of stress-strain curve on tear strength.

In addition to the yarn properties just discussed, fabric structure plays a highly significant role in tear strength considerations, all or most of which can be considered as influencing the general mobility or distortability of the fabric structure in the local active region of tear. Although not too clearly delineated by Fig. 1 be-

cause of the complexity of three-dimensional drawing, the tendency of the two systems of yarns to reorient themselves is accompanied by slippage of one system over the other. For example, the originally longitudinal yarns try to slide over the cross-threads, and both the ease and the extent to which such motion takes place will determine the total size of the del and hence the total load-carrying capacity prior to thread rupture. Such sliding takes place, being resisted by pressure at thread interlacing, until either a del yarn breaks or until the longitudinal threads jam. If the resistance to sliding is sufficiently great, thread rupture will take place with only a few yarns acting in the del. Similarly, even if sliding is not resisted, jamming of the longitudinal threads creates a limit to the extent of local deformation which will occur and the extent of sliding prior to jamming will determine the size of the del at thread rupture. Thus, from these and other considerations it would be expected that the higher the cover factor of the longitudinal threads, the lower the tear strength for a given cross-thread construction. Results of tear tests which show this effect are given

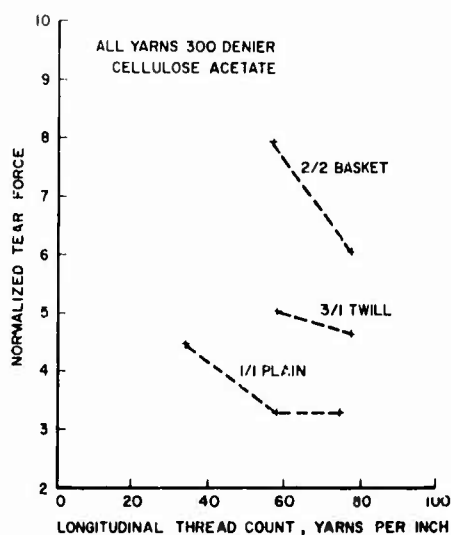


Fig. 3. Normalized tear force vs. longitudinal thread count—continuous filament fabrics.

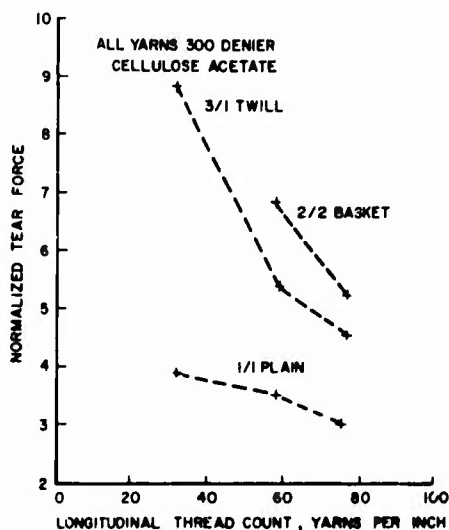


Fig. 4. Normalized tear force vs. longitudinal thread count—staple fiber fabrics.

in Figs. 3 and 4 for a variety of fabrics made of both filament and spun cellulose acetate fiber, and for three weaves. In all cases it is clear that increases in longitudinal thread cover factor, arrived at for these cases by increases in the number of longitudinal threads per inch, produce decreases in the tear strength. Attention is also directed to the extremely large effect produced by weave pattern variations as indicated in Figs. 3 and 4. In all cases, weaves with long floats -- or to paraphrase a description made by one of my colleagues, those weaves with the fewest number of contiguous alternating intersections or interlacings per repeat of the fabric weave pattern -- produce the higher tear strength. This is believed to be solely the result of diminished interference with thread and fabric

distortion created by using such weaves. It also should be noted that, in general, increases in the number of longitudinal threads are more detrimental to distortable weaves than to the non-distortable. Thus the plain weave fabrics of Figs. 3 and 4, which have a high number of alternating intersections per repeat and which therefore are the most predisposed to immobility on a weave basis, are not as sensitive to thread spacing changes as are those weaves with long floats. These relationships are not specific to the particular fabrics used herein for illustrative purposes, but are essentially true for all fiber types.

There is another interesting factor involved in fabric construction which oftentimes plays a significant role in tear strength on the basis of fabric mobility; namely, crimp magnitude and its distribution between the warp and filling yarn systems. Although there is not as yet a scientific basis for quantitative predictions of the effect, certain extreme cases can be cited. For example, consider a tear across the warp yarn system, the filling yarn being the longitudinal ones. The longitudinal thread cover factor will determine the limit of thread sliding prior to jamming, as previously described. Additionally, for a warp crimp close to zero (high filling crimp), it is clear that resistance to sliding will be very low, i.e., the highly crimped filling yarns will encounter little resistance in sliding over the almost straight warp; and, therefore, a relatively large del will be formed at a low externally applied force resulting in a relatively high tear strength. For this type of fabric, tearing across the highly crimped filling will evoke relatively higher resistance to fabric distortion since the low crimp warp would not easily slide across the high crimp filling, and thus a relatively low tear strength will result. The situation is illustrated in Fig. 5 for the two cases cited. A typical experimental result which verifies this effect is shown in Table 1.

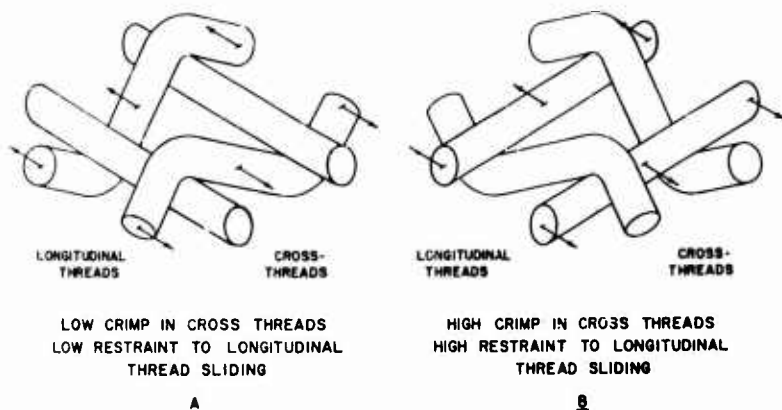


Fig. 5.

TABLE 1
ILLUSTRATION OF EFFECT OF CRIMP BALANCE
Continuous Filament Acetate -- 2 x 2 Basket Weave

	<u>Warp</u>	<u>Filling</u>
Yarn Denier	300	300
Yarn Twist, TPI	6	6
Thread Count, per inch	55	54
Yarn Crimp, %	1.4	9.4
Tongue Tear Strength, lb	9.0	6.9

Except for crimp differences the warp and filling geometries are as alike as commercially possible. Individual warp and filling yarn strengths and extensibilities are negligibly different, and yet the warp tear strength is some 30% stronger than is the filling. In certain fabrics where crimp interchange is possible, application of widthwise tension to more nearly balance crimps can produce more nearly equal warp and filling tear strengths. However, it is not possible to predict magnitudes of such effects since it is as yet unknown whether, for example, a crimp distribution of 5% x 5% will involve any less restriction to fabric distortion for both tear directions than a crimp distribution of 1% x 9% does in tearing across the filling. Certainly, if a redistribution of crimp took

place so that crimps of 9% \times 1% resulted, one would expect a greatly increased fillingwise tear strength. On the other hand, if the total extent of distortion is small because of rapid tendency to jam, then crimp differences per se may play a small role in influencing tear strength.

Tear strength is altered not only by changing fabric distortability by fabric geometric changes but by finishing as well. In the case of cotton fabrics, such preparatory finishing steps as de-sizing, scouring, and bleaching and dyeing have the effect of altering surface characteristics. In particular, the removal of natural waxes, pectins, and other constituents which can change the inherent lubricity of the system can influence fabric distortability. In Fig. 6 are shown plots of tear strength at various

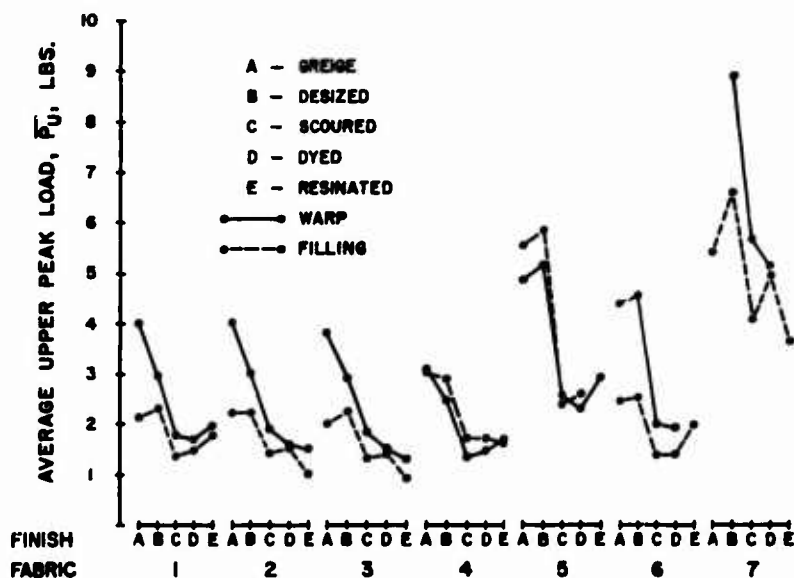


Fig. 6. Effect of finishing treatments on tear strength.

stages of finishing from the loom state through resin treatment for a variety of cotton fabrics of different weight. Aside from the last point on each graph which represents resin-treated goods, fabric tensile properties in each case were relatively unaltered as a result of the finishing treatments. In many cases, tensile strength

was slightly increased over the loom state (greige fabric). While there were some fabric geometric changes induced by finishing, these were slight, and their influence found to be minor in general. Note, however, the large changes in tear strength, particularly as a result of scouring, where most of the natural lubricants are removed. In every single case, changes in fabric distortability were chiefly responsible for the severe effect produced by the scouring operation. A measure of fabric distortability with respect to the size and uniformity of load distribution amongst yarns in the del is given by the effective number of threads rupturing per load-drop during tear. In tearing through one inch of a fabric containing 50 cross-threads per inch, effectively one thread is breaking per peak if 50 peaks are observed. If 25 peaks are observed, then two threads are breaking per peak, indicating better load distribution and a higher tear strength than in the previous case. Table 2 gives the number of threads breaking per peak before and after scouring of the cotton fabrics involved.

TABLE 2
EFFECT OF SCOURING ON THREADS RUPTURING PER PEAK

<u>Fabric Number</u>	<u>Tear Across</u>	<u>Number of Threads per Peak</u>	
		<u>Desized</u>	<u>Scoured</u>
1	Warp	1.55	1.13
	Filling	1.47	1.10
2	Warp	1.60	1.12
	Filling	1.60	1.08
3	Warp	1.59	1.09
	Filling	1.50	1.10
4	Warp	1.44	1.06
	Filling	1.50	1.08
5	Warp	2.28	1.73
	Filling	1.41	1.00
6	Warp	2.46	1.73
	Filling	1.92	1.06
7	Warp	3.55	1.36
	Filling	1.71	1.00

Clearly, scouring has reduced fabric distortability in every case sufficiently so that the number of threads supporting the tear force is reduced significantly, the reductions ranging from 30 to 70%. Successful commercial counter-approaches to this type of effect are employed through addition of lubricants or softeners to fabrics to increase their tear strength, particularly when resins which can produce hindrances to mobility are cured in fabrics.

The numerous inferences regarding the importance of fabric distortability to tear strength probably has predisposed you to anticipate what effects coating interactions can have. Obviously, coatings, if they adhere well, can interfere with fabric distortability and can affect the "natural" response of the fabric deleteriously. If the coating is heavy enough and strong enough, the force required to tear through it alone, presumably in shear, might overcome any diminution in intrinsic fabric tear.

However, there are some subtle aspects to the question of interaction to very few of which definitive answers can be given, but which require discussion. In the first place, the modulus of elasticity of the coating can determine to a considerable extent how much the base fabric distortability is altered. Not only could the lack of ability of the coating to distort affect the overall size of the del, but could also prevent reorientation of the cross-threads to line up with the direction of pull. This, of course, will result in a very low tear strength because only a component of the yarn strength is being utilized effectively. Unfortunately, since the mechanics of deformation in tearing are so extremely complex, it is not yet possible to define adequately just which modulus of the coating is significant. Certainly, modulus in tension and possibly in shear is meaningful in characterizing distortability, but the part each plays has not yet been determined adequately. At this stage of the state of the science, all one can do is to use

the term "distortability" in its broadest sense without characterizing how to measure it. Moreover, and as will be discussed in greater detail later, not only can intrinsic coating properties but also location of coatings influence mobility. Location of the coating, in turn, can be influenced not only by the method of coating, but also by the fabric structure. Since fabric structure also determines uncoated fabric tear strength, interaction becomes somewhat of a vicious circle which can be broken only by extensive and painstaking research efforts involving rather broad experimental approaches, followed by careful analytic work. Without the results of such a broad analytic approach to present, I intend to limit my remarks to pointing out a few interesting results on coating effects which may stimulate your thinking on the problem.

First, to illustrate the effect of coating modulus changes I will present the results of some studies made for the Office of The Quartermaster General on the relationship between plasticizer content of coating and tear strength. A series of coated fabrics, all employing the same nylon base fabric, was prepared by the Hodgman Rubber Company. The coatings formulations were not necessarily considered to be commercially utilizable, but were picked to yield extremes so that general principles would be ascertained or verified. The coating material was polyvinyl butyral with increasing parts of plasticizer per 100 parts of resin. The base fabric was a 1.6 oz nylon plain weave used for ponchos. Specifications of the coatings and physical properties are given in Table 3. The increase in tensile deformability with increasing plasticizer content of the coating is apparent from the load required to strain the coating 100% in tension. The absolute value of deformability depends upon testing speed, but as broad a range of "moduli" as that shown in Table 3 was found to exist at all speeds. The results of tear tests for these materials are given in Table 4. There is no doubt from

these results that increase in plasticizer content can increase markedly the tear strength of the coated fabrics, in some cases to a higher level than the original uncoated. These effects are believed to be the result of increased fabric distortability arising both from the lowered coating modulus and also any enhanced fabric lubricity emanating from excess plasticizer.

TABLE 3
CHARACTERISTICS OF COATINGS ON NYLON PONCHO CLOTH
(82 x 82; 1.6 oz per sq yd)

<u>Fabric Number</u>	<u>Percent Plasti- cizer*</u>	<u>Total Coating Wt, oz/sq yd</u>	<u>Number of Coats</u>		<u>Modulus, psi Stress at 100% Elongation</u>
			<u>First Side</u>	<u>Second Side</u>	
TD 6579 E	40	5.3	9	11	560
TD 6581 E	70	5.7	9	11	190
TD 6583 E	100	6.1	8	8	101
TD 6585 E	130	6.2	8	9	75
TD 6659 E	150	6.1	2	14	71
TD 6699 E	175	6.4	0	1	--
TD 6663 E	200	5.2	0	14	45

* Parts of Plasticizer per 100-parts resin.

TABLE 4
EFFECT OF PLASTICIZER CONTENT OF POLYVINYL BUTYRAL
COATED NYLON PONCHO FABRIC TEAR STRENGTH

<u>Fabric Number</u>	<u>Percent Plasticizer</u>	<u>Tear Strength*, lb</u>	
		<u>12" per min **</u>	<u>50" per min**</u>
Uncoated Control	-	10.8	11.1
TD 6579 E	40	7.7	6.5
TD 6581 E	70	10.2	10.9
TD 6583 E	100	10.5	10.7
TD 6585 E	130	11.0	13.1
TD 6659 E	150	12.0	13.2
TD 6699 E	175	12.5	13.3
TD 6663 E	200	14.9	17.5

* The tear strength values are given as energies to tear through one inch of fabric, with units of pounds. These are directly functional with tear load in pounds.

** Pulling jaw speed.

The extraordinarily high values for the fabrics with 200% plasticizer can be ascribed not only to increased deformability but also to the fact that this fabric was coated only on one side, presumably with lesser penetration of the coating into the fabric interstices than was the case for most of the other fabrics in this series. Penetration, i.e., location of the coating, as alluded to earlier, can have a significant effect on tear strength. Certainly, if complete penetration through interstices takes place, the resistance to fabric distortion would be quite great. Recollecting the earlier discussion on the mechanics involved in base fabric tear, slippage of the longitudinal yarns would be resisted immediately, i.e., effective jamming of these yarns could have occurred prior to external load imposition, making for a small del with low resultant tear strength. Thus, in effect, both the ease and extent of deformability would be expected to decrease with increasing penetration.

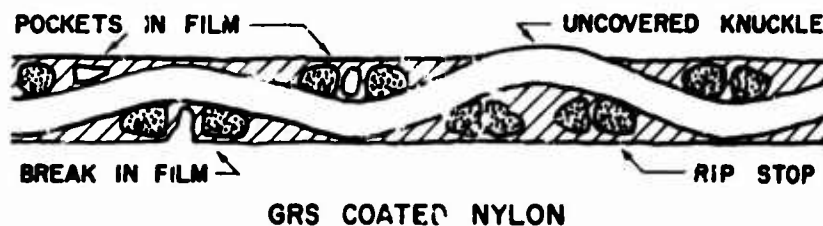
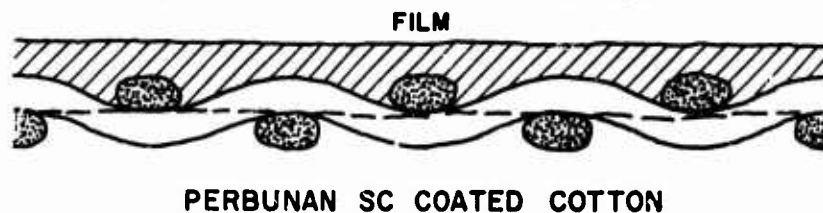


Fig. 7. Warpwise cross-sections of coated fabrics.

TABLE 5
RANK CORRELATION OF COATING PENETRATION
WITH TEAR PROPERTIES*

Fabric Number	Relative Order of		
	Increasing Coating Penetration (visual estimate)	Decreasing Tongue Tear Strength Warp	Filling
Nylon Base			
Uncoated	1	1	1
1504	2	2	3
1560	3	3	2
1208	4	4	4
548	5	5	5
466	6-7	6	7
296	6-7	7	6

Range of values -- no coating to coated both sides -- 16.81 to
2.87

Cotton Base

376	1	1	1
1218	2	4	2
1314	3	3	4
1312	4	2	3

Range of values -- all coated 1 side, slight to
medium penetration ----- 5.19 to
2.96

* The range of tear strength values are those of energy per inch of tear.

As part of a study on the effects of aging on coated-fabric tear strength, two series of unaged coated fabrics, one of nylon and the other of cotton were examined for tear strength. The cotton base fabric was a fairly tight plain weave, while the nylon was a relatively loose 2/1 twill. Typical of the structure of these types of fabrics are the representative cross-sections made using the Camera Lucida for each of the types, as shown in Fig. 7. While there may have been some differences involved in the chemical compounding of the coatings used on each fabric, these did not

appear to influence mechanical properties in tension to anywhere near the degree which would be expected from the tear performance. All coated fabrics of this series were examined on cross-section, and a visual estimate made of the degree of penetration. Results for both the nylon and cotton fabrics are shown in Table 5.

Referring first to the nylon series, there was little difficulty in ascertaining by observation the relative degree of penetration and, in addition, there existed a broad range of degrees. Similarly, tear strength varied over a broad range also. While tensile strength dropped with increasing penetration, it dropped at a considerably lower rate than did tear strength so that the ratio of tongue tear to strip-tensile continually dropped. The correlation between low tear strength and increasing penetration for the nylon series is excellent.

For the cotton base coated fabric, the evidence was inconclusive concerning the effect of degree of penetration. Although there is evidence of a trend, it is not striking. Moreover, the range of values of tear strength for the cottons is not as great as for the nylon. Similarly, the range in degree of penetration was less for the cotton than for the nylons. It would seem that the cotton was more difficult to penetrate during coating and even when penetrated, was not particularly susceptible to coating interference, since the yarns were not as distortable because of the plain weave construction and the intrinsically lower extensibility of cotton. On the other hand, the nylon was easier to penetrate and also was more susceptible to coating interference, because the more open weave and higher extensibility of nylon necessitates greater yarn movement during a tear.

Not only can location of coating play a significant role in determining distortability of the original fabric, but it also can influence the effect of aging. Generally, aging produces degradation

of tear strength of coated fabrics. This degradation is the sum of degradation in the base fabric properties plus any change in coating interference with aging. Obviously, the nature of the environment in which the aging is taking place will influence both the total extent of degradation and also its distribution either into base fabric losses or coating changes. For example, for a light coating applied to nylon, continuous exposure to a high ultra-violet atmosphere could cause rapid breakdown in nylon physical properties, and this would impair coated-fabric tear strength. Similarly, atmospheres which tend to stiffen a coating would affect primarily the fabric-coating interaction, particularly if the coating is so located that it can exert a significant role.

Illustrative of this type of consideration are the plots of tear strength losses shown in Fig. 8. Here is shown the percent loss in tear strength versus hours of heat aging in a 220° oven, a purely arbitrary condition of aging. One set of curves is for a lightweight, SBR-coated nylon, while the other is for a Perbunan SC-coated cotton of heavier weight than the nylon. For each material, three

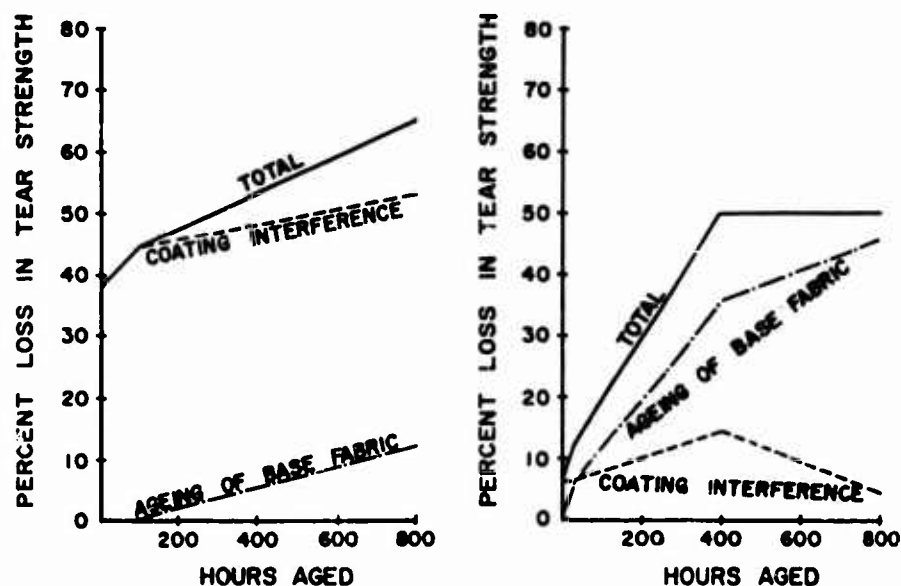


Fig. 8. Distribution of tear strength losses
oven aging at 220°F

separate curves are given showing the distribution of causes of loss in tear strength. The loss due to aging of the base fabric was determined by comparing the unaged uncoated-fabric tear strength to the tear strength of the base fabric removed from the aged coated fabric through chemical extraction. Extensive control tests in solvent soaking ensured that the extraction procedure itself did not damage base fabric strength. The total loss was computed as the difference between unaged uncoated-base-fabric tear strength and that of the aged coated fabric. The effect of coating interference or interaction is calculable as the difference between the total loss and that due to aging of the base fabric.

Note that for the case of the thin nylon fabric, coating interference played a dominant role in the early stages of aging and continued to exert an increasing deleterious effect with time of exposure. Although base fabric degradation also increased with time, coating interference played the more significant role in loss in tear. For the cotton, for which penetration effects are less than for the nylon, aging of the base fabric was the most dominant effect. Continuous exposure to heat in the case of the Perbunan-coated cotton ultimately stiffened and embrittled the coating to such an extent that the coating essentially powdered off. As a result, the coating did not exert any significant restraint to the fabric mobility at the loads involved in tear. Successful applications have been made of the principles involved in interaction as described in all of the foregoing. For example, the significance of yarn mobility was utilized to produce a nylon poncho twill fabric having twice the tear strength of a standard, both in the coated and uncoated condition. This was accomplished by padding on a small amount of lubricant such as DOP plasticizer or sulphonated castor oil to the base fabric prior to coating.

As I indicated at the beginning of this paper, interactions involved in tear have been employed as the main theme. This, by

no means, represents the only mechanical performance characteristic of significance in coated fabrics. There are many other important considerations which depend upon interaction under stress. For example, cracking of coatings under load is a function of fabric versus coating extensibility usually while under biaxial loading. Uncoated-fabric extensibility is partially dependent upon state of crimp in the fabric. Ease of removal of this crimp can alter significantly the tensile behavior of fabrics under biaxial stress. Restraints imposed by coatings, either by fiber bonding or blocking of yarn motion when the fabric interstices are penetrated, can produce severe differences in coated fabric performance. Similarly, changes in air or gas flow through coated fabric, primarily a diffusion phenomenon, is a function of molecular orientation of the coating, and this can change with fabric structure interacting with the coating under the biaxial loading involved in the end use condition. The flex endurance of fabrics is a function of the fabric geometry and its effect on relative freedom of motion of the elements of the structure. Certainly, restraints imposed by coatings can play a significant role in repeated bending of coated fabrics.

While a great deal is known about the performance of base fabrics for these and other use conditions, specific information on how fabrics of various fiber contents and geometries interact with coatings of various properties is not known. One might speculate as to whether or not the application of coatings tends to level out differences in base fabric performance. Certainly for tear strength considerations this was not found to be the case. It is suggested that only through systematic, long-range research can the sought answers be found.

Certain of the data used herein were obtained on studies performed for the Office of The Quartermaster General. Support of this research is acknowledged, as are the contributions thereto of the author's colleagues, E. V. Painter and E. R. Kaswell.

References

1. Teixeira, N. A., Platt, M. M., and Hamburger, W. J., Relation of Certain Geometric Factors to the Tear Strength of Woven Fabrics, Textile Research Journal, 25, 838 (1955).
2. Krook, C. M. and Fox, K. R., Study of the tongue-tear test, Textile Research Journal, 15, 389 (1945).

TECHNICAL SESSION NO. 2

Stanley Backer, presiding

Chairman Backer: Mr. Corry, our next speaker, for many years was in charge of the Textile Branch, Materials Laboratory at the Wright Air Development Center. He is presently Laboratory Manager for Landers Corporation of Toledo, Ohio.

FABRICS FOR COATING - DESIGN AND CONSTRUCTION

WILLIAM A. CORRY -- Graduated from Georgia Tech in 1940 with a B. S. in Textile Engineering and subsequently worked with General Tire and Rubber Company, Athens Manufacturing Company and the U. S. Quartermaster. From 1946 through 1954 he was Chief of the Textiles Branch of the Materials Laboratory at Wright Air Development Center, Dayton, Ohio. For the past four years, he has been Laboratory Manager for The Landers Corporation, Toledo, Ohio. He is presently a member of ASTM and AATCC.

The ambition of the fabric engineer to be able to take a slide rule, physical property tables, pencil, and paper and construct an ideal fabric for a given end use. He is certainly much nearer this goal today than he has ever been, but he still has a long way to go.

I want to review some of the means available for the design of fabrics, some of the gaps in our knowledge which handicap our efforts, and some factors which are peculiar to fabrics for coating. The following are some of the more important characteristics of a coating fabric for which we might want to design:

1. Breaking strength.
2. Weight.

3. Cost.
4. Tear.
5. Fabric tightness and bulk.

We can engineer these properties with varying degrees of accuracy. Except for tear, we should have reasonable success with these five properties as long as we can lean on some empirical observations and past experience. Let us consider some of the calculations we should make in moving from our first conception of a fabric to a weaving specification.

1. Strength. Fabric strength is dependent, of course, almost entirely upon yarn strength. This calculation is straightforward and, except in jammed structures, can be made with confidence for strength determined by the raveled-strip method. Basically, the strength of the warp or filling is equal to the strength of the individual yarns times the number of yarns times some efficiency factor. This efficiency factor is normally in an 85% to 95% range except for yarns having a high initial modulus woven into dense fabrics, when it can be appreciably less. A convenient calculation is as follows:

$$\text{Eq 1} \quad \text{BS} = \frac{\text{T} \times \text{C} \times \text{N} \times \text{E}}{453.6}$$

Where

BS = Breaking strength in pounds per inch,
determined by the raveled-strip method.

T = Yarn tenacity in grams per denier.

C = Yarns per inch.

N = Yarn denier.

E = Efficiency factor.

You note that I have carefully avoided giving an estimation of grab-method tensile, although textile designers are often called on to do this to meet customer specifications. The increase in tensile to be estimated is dependent upon so many fabric variables that

experience, comparisons, and prayerful guesses are all that I would dare prescribe for this step. Coating adds new complications to grab-strength estimations. Stiffer coatings, more strike-through, stronger coatings, all tend to increase grab tensile. The similarity of fabric modulus to coating modulus must certainly have its effect.

2. Weight. Rather close estimations of weight can be made without difficulty if crimp can be approximated. The work of Peirce (1) and various tables are available for this. A simple equation for weight is as follows:

$$\text{Eq 2} \quad W = C \times N \times (1.0 + \text{crimp}) \times 0.000129$$

where weight is ounces per square yard and crimp is fractional, not percentage.

3. Cost. The cost factors in designing fabrics for coating are, of course, basically the same as for fabrics for other uses. As fabrics to be coated are nearly always in the industrial family, the basic consideration of cost per unit strength is quite important. The continuous filament synthetic yarns offer attractive possibilities for an economical strength-cost relationship. Table 1 gives a comparison of approximate yarn costs for some of the major fibers.

TABLE 1

<u>Yarns</u>	<u>Cost/lb</u>	<u>Tenacity (app.)</u>	<u>Cost per unit strength</u>
Carded cotton *(15s)	\$0.50	1.5	33
210 denier nylon	1.49	7.5	20
300 denier rayon	0.74	3.0	25
600 denier rayon	0.70	3.0	23

* estimated.

This table serves to illustrate that there can be a cost saving when one is buying strength primarily by using continuous filament yarns. If an additional primer is needed to obtain satisfactory adhesion

between the fabric and the coating, some or all of this advantage may be lost. However, the remarkable success of the all nylon fabrics as tarpaulins and the like must make us all aware of the unusual potential of synthetic yarns in designing new fabrics. The host of new staple and filament yarns which are becoming available in various sizes and shapes offer new opportunities for inventiveness to all fabric designers.

4. Tear. In most of the applications of coated fabrics, tear strength is regarded as more important than breaking strength. The usual coating operation dramatically lowers the fabric tear strength by partly immobilizing the threads, so that it behooves the fabric designer to pay particular attention to those factors which affect tear strength. The construction variables which apply to the design of high tear strength fabrics for clothing or other uses certainly apply to fabrics for coating. In addition, one important variable should be considered. As the degree of "strike-through" or penetration of the coating has a profound effect on final tear strength, attention should be given to those factors which permit adequate adhesion with minimum coating penetration. Some of the familiar construction variables of which the designer should be mindful are as follows:

1. Weave -- generally, fewer thread interlacings provide higher tear strength.
2. An increase in thread count or yarn size in one direction reduces tear in the other direction.
3. Smoother yarn surfaces improve tear.
4. Increase in yarn strength improves tear strength.
5. An increase in yarn twist, especially in filament yarns, is likely to reduce tear strength.
6. The properties of the coating itself have an important effect on tear.

5. Fabric Thickness and Tightness. The degree of fabric tightness and bulk are among the more important fabric characteristics

we need to consider in designing new fabrics for coating. These factors, we know, can be most important in determining the strike-through of a given coating compound and hence can affect tear strength. They affect the weight of coating necessary to give a certain level of waterproofness. They affect stiffness, resistance to weathering, cost, coating weight, processability, and in fact, nearly all the properties of coated fabrics. Let us consider bulk first. It is obvious that for a fabric having balanced crimp the bulk is equal to the sum of the warp yarn and the filling yarn diameters. We also know that in a fabric having the warp yarn pulled completely straight (no warp crimp) the thickness is equal to the warp yarn diameter plus twice the filling yarn diameter. The problem in predicting fabric thickness is in knowing the yarn dimensions and the degree of crimp. Staple yarn diameter will, in general, be predictable from the familiar equation.

$$\text{Eq 3} \qquad d = k\sqrt{N}$$

Where

d = diameter of a round yarn.

k = a constant.

N = yarn number in a direct yarn numbering system;
e.g., deniers.

This relationship holds well enough for the usual cotton yarns to give an approximation of raw fabric thickness as we measure it with the common presser foot gauges. It misses rather badly in considering fabrics woven from low-twist, continuous-filament yarns. For convenience, I shall draw on some data and observations made a few years ago in considering continuous-filament yarns for parachute cloth design (2). These are sufficiently general so they illustrate what we may do.

The experiments of Taylor (3) have established the relationship between yarn diameter and twist for raw, uncompressed nylon, Orlon,

Dacron, and viscose rayon. It was shown that yarn denier decreased with increasing twist for all the deniers and polymer types tested to a minimum value at about 10 to 15 turns per inch and that (especially for the higher denier yarns) the yarn diameters increased slightly when higher twists were employed. In this investigation no attempt was made to measure yarn dimensions under various pressures. Taylor's data, therefore, probably represent the minimum widths (and maximum thicknesses) obtainable with the various yarns as they would lie in the cloth. As these data were determined on uncompressed and hence essentially round yarns, the diameter should be predicted by Eq 3. For nylon yarns a value of $k = 5.1 \times 10^{-4}$ gives good results, as shown in Table 2, comparing columns (C) and (D).

TABLE 2

<u>Yarn denier and filament count (A)</u>	<u>Maximum theoretical width (B)</u>	<u>Minimum theoretical width (C)</u>	<u>Measured width (D)</u>
20/7	5.2	2.28	2.16
30/10	7.6	2.79	2.71
40/13	10.0	3.22	3.27
50/17	12.8	3.61	--
70/34	21.4	4.26	4.35
100/34	25.6	5.10	5.26
210/34	37.0	7.40	7.48
260/17	29.1	8.23	8.15
840/140	150.3	14.80	--

The condition of maximum yarn width (and minimum thickness) would be obtained if each filament of a yarn were laid side by side, just touching in the cloth. If nylon is considered to have perfectly circular filament, a fairly accurate prediction of maximum yarn width can be made as follows:

$$\text{Eq 4} \quad d_e = k\sqrt{N}\sqrt{Z}$$

Where

d_e = effective yarn width in inches.

k = a constant (equal to 4.37×10^{-4} for nylon).

N = yarn denier.

Z = filaments per yarn.

Table 2 includes calculated maximum and minimum yarn widths and the observed widths for raw yarns twisted to 15 turns per inch as reported by Taylor. As all yarns are compressible the absolute minimum yarn widths are not obtainable in a practical fabric. Hence yarn widths within the fabric are normally intermediate between the maximum and minimum. The thinnest possible fabric made from a given yarn would be two filaments thick. However, even if it were possible to weave such a structure, it would be too weak for most purposes.

Since strength is a primary consideration, we must incorporate sufficient yarn and, therefore, a definite number of filaments to meet this requirement. Having settled on strength, we can then select a yarn which will be as strong as possible for a given situation. We then can determine what minimum fabric thickness may be obtained. It is obvious that for bulk determinations for filament fabrics, one should not consider yarn, but rather the filament as the basic unit. An example is given to demonstrate what may be done in the way of calculation. Taking a fabric with a construction of 76 ends and picks of 100 denier 34 filament yarns and using idealized, perfectly-symmetrical, perfectly-even filaments, the minimum thickness may be calculated as follows for a plain weave cloth, assuming balanced crimp. The yarn spacing (center to center of the filament bundles) is given by

Eq 5
$$p = \frac{1}{C}$$

Where

p = yarn spacing.

C = thread count (warp or filling).

which for a thread count of 76 equals 0.0132". Now calculating the maximum width (which would give minimum thickness) from Eq 4

$$\begin{aligned} d_e &= 4.37 \times 10^{-4} \sqrt{N} \sqrt{Z} \\ &= 4.37 \times 10^{-4} \sqrt{100} \sqrt{34} \\ &= 0.0254", \text{ which exceeds the} \\ &\quad \text{available lateral space.} \end{aligned}$$

It becomes obvious then that even in this idealized structure the filaments must be piled on top of each other. Two possible combinations of the 34 filaments are shown in Fig. 1 and, again idealizing, they are shown as nesting. The lateral dimensions are obviously 17 1/2 times the filament diameter and 12 times the filament diameter, respectively. The thicknesses are respectively



TWO LAYER CONFIGURATION



THREE LAYER CONFIGURATION

Fig. 1.

2 and 3 times the filament diameter, reduced by about 10% to account for the nesting. The filament diameter is given by

Eq 6
$$d_z = 4.37 \times 10^{-4} \sqrt{\frac{N}{Z}}$$

where d_z = the diameter of a nylon filament which in a 100 denier 34 filament yarn is about 0.00075".

Now for a plain weave we must provide an additional space in the place of the fabric equal to the thickness of the yarn for each

crossing thread to pass. In other words, for a plain weave, square fabric, a spacing for each yarn must be provided which is equal to the width of the yarn plus the thickness. Now referring again to Fig. 1 we see that for two layers of filaments the minimum lateral dimension for a two filament layer configuration would be

$$\begin{aligned}d_e &= 0.00075 (17 \frac{1}{2} + 2) \\&= 0.0146''\end{aligned}$$

and for a 3 layer configuration would be

$$\begin{aligned}d_e &= 0.00075 (12 + 3) \\&= 0.0112''\end{aligned}$$

It appears then that for the specified conditions a minimum fabric thickness would be twice the thickness of the three layer configuration.

$$\text{Eq 7} \quad G_{mn} = 2(L \times 4.37 \times 10^{-4} \sqrt{\frac{N}{Z}})$$

or

$$\begin{aligned}G_{mn} &= 2(3 \times 0.00075) \\&= 0.0045''\end{aligned}$$

where

G_{mn} = minimum fabric thickness.

L = number of layers of filaments
which, if we consider that the filaments
could "nest" would be about 0.6041.

Again making the simplifying assumptions we may calculate maximum thickness, for balanced crimp, from a modification of Eq 3.

$$\text{Eq 8} \quad G_{mx} = 2k\sqrt{N}$$

and for the above fabric

$$\begin{aligned}G_{mx} &= 2 \times 0.0051\sqrt{100} \\&= 0.0102''\end{aligned}$$

where

G_{mx} = maximum thickness.

We can see that, theoretically at least, a fabric having 76 ends and 76 picks of 100 denier 34 filament nylon can be varied in thickness, by changes in twist alone, from about 0.0041 to 0.0102". The limits of fabric thickness could be obtained, if at all, only with difficulty. However, an experimental fabric woven to the texture and with the yarn given above actually approached the lower limit. When scoured and moderately calendered, it gave an actual thickness of 0.0043". A similar fabric woven with warp and filling yarns, both having 10 turns twist, gave a thickness of 0.0060".

Fabric "tightness" is generally given in terms of "cover factors" and may be described reasonably well by the usual form.

$$\text{Eq 9} \quad K_c = C_w d_w + C_f d_f - (C_w d_w \times C_f d_f)$$

where

K_c = cloth cover factor.

C = thread count.

d = effective yarn width in the cloth, w and f indicate warp and filling respectively.

Approximating K_c for many fabrics would not be troublesome if we could estimate values of d under various conditions. Staple yarns are conveniently round when spun and by estimating a specific volume of 1.1, Peirce and others have given us means of designing for a wide range of cover factors with some precision. In fabrics for coating we must remember that the yarns are usually flattened by the coating process. In addition, it is common practice to calender fabrics before coating to close them up and smooth the surface. Yarn twist naturally will affect the degree of flattening which the yarn will accept; softer twisted filling yarns being more "flattenable" than the harder twisted warp yarns. Fortunately, designers usually have a wide range of fabrics available as patterns. A few judicious measurements with a microscope having a stage micrometer can help us compensate for the errors

in yarn dimensions which would occur if we attempted to use uncorrected equations. While the errors would be appreciable with staple yarns, they would not be tolerable in the case of filament yarns. Referring again to Table 2 we see that a 70 denier 34 filament nylon yarn might vary theoretically in effective width from 0.0214 to 0.00426" -- a 500% variation. Table 3 gives data on measurements made on this yarn in a fabric, when it was employed as filling and the twist was varied.

TABLE 3
OBSERVED WIDTHS OF 70 DENIER 34 FILAMENT
NYLON FILLING YARN IN AN UNCALENDERED CLOTH

<u>Twist</u> <u>(Turns/Inch)</u>	<u>Width</u> <u>(Inches)</u>
1/2	0.0123
2 1/2	0.0115
5	0.0112
7	0.0105
15	0.0088
20	0.0081
35	0.0055

I mentioned earlier that fabric thickness is dependent upon crimp balance. This fact and the implications arising from it seem to me to offer the most fertile field for research on fabrics for coating. Most coating processes impose considerable stress on the warp yarns of the fabric, causing a crimp -- interchange and changing in the shape and size of the fabric pores. When the coating is applied the fabric structure is more or less "frozen" in the resulting position. If the wonderful work done by Backer (4) could be expanded to develop cross sectional areas and pore volumes of fabrics having zero warp crimp, we might find means of providing equivalent properties with lower weights of coating. This might also help us to improve control of strike-through of cements or dispersion coating, thus improving tear properties. This unbalanced situation is very different from the usual balanced

crimp studies which the textile literature dwells upon at some length. In a paper presented before the Fiber Society, Dr. Milton Platt pointed out that the air flow through fabrics must be affected appreciably by a "relatively straight warp, crimped filling" configuration. This distribution of crimp must be important to coating strike-through, abrasion resistance, width, weathering resistance, thickness, tear strength, waterproofness, and possibly other critical properties of coated fabrics. Studies based on the better understanding and control of crimp should be most profitable.

Table 4 gives some data on flow of two commercial vinyl resin dispersions through the three cylindrical orifices commonly used with the Severs rheometer. You note the flow is proportional, approximately, to the square of the area, or the fourth power of the diameter of the orifice. I do not propose that strike-through of a dispersion under a coating knife would follow this exact pattern but surely it is sensitive in the extreme to pore size and configuration.

TABLE 4
DATA ON FLOW OF TWO DISPERSIONS
THREE SEVERS RHEOMETER ORIFICES

TABLE 4a

DISPERSION S181 -- FLOW MEASURED AT 80 PSI LINE PRESSURE

Orifice	A1	A2	A3	Ratio	Ratio
Area, cm ³	0.32	0.075	0.024		
Flow, cm ³ /sec	Q1	Q2	Q3		
	236	13	1.5		
$\left(\frac{A1}{A2}\right)^2$				18.3	
$\frac{Q1}{Q2}$				18.1	
$\left(\frac{A2}{A3}\right)^2$					9.6
$\frac{Q2}{Q3}$					8.7

TABLE 4b

DISPERSION S181 -- FLOW MEASURED AT 60 PSI LINE PRESSURE

Orifice	A1	A2	A3	Ratio	Ratio
Area, cm ³	0.32	0.075	0.024		
Flow, cm ³ /sec	Q1 135	Q2 9.8	Q3 1.0		
$\left(\frac{A1}{A2}\right)^2$				18.3	
$\frac{Q1}{Q2}$				13.8	
$\left(\frac{A2}{A3}\right)^2$					9.6
$\frac{Q2}{Q3}$					9.8

TABLE 4c

DISPERSION S178 -- FLOW MEASURED AT 80 PSI LINE PRESSURE

Orifice	A1	A2	A3	Ratio	Ratio
Area, cm ³	0.32	0.075	0.024		
Flow, cm ³ /sec	Q1 107	Q2 5.17	Q3 0.48		
$\left(\frac{A1}{A2}\right)^2$				18.3	
$\frac{Q1}{Q2}$				20.7	
$\left(\frac{A2}{A3}\right)^2$					9.6
$\frac{Q2}{Q3}$					10.8

TABLE 4d

DISPERSION S178 -- FLOW MEASURED AT 60 PSI LINE PRESSURE

Orifice	A1	A2	A3	Ratio	Ratio
Area, cm ³	0.32	0.075	0.024		
Flow, cm ³ /sec	Q1	Q2	Q3		
	77.5	3.75	0.34		
$\left(\frac{A1}{A2}\right)^2$				18.3	
$\frac{Q1}{Q2}$				20.6	
$\left(\frac{A2}{A3}\right)^2$					9.6
$\frac{Q2}{Q3}$					11.0

I could not leave a discussion of fabrics for coating without commenting on two extremely important and practical aspects of fabrics for coating. First, those factors which produce knots and slubs in fabrics are poisonous to coaters. A knot or slub can make a surface defect thicker than the coating itself in many cases. Hence great care should be taken by the designer and weaver to select those processes and yarns which will produce a minimum of slubs and knots. Secondly, any factor which produces tight selvages or bagginess in the goods is certain to cause the fabric to be extremely difficult to coat and the coated fabric to be troublesome in fabrication. These last two comments are brief but serious ones, for the benefits of an otherwise good fabric design can be completely obviated if the coating surface is irregular or unstable.

References

1. Peirce, F. T., Journal of the Textile Institute, 28, (3) (1937).
2. Corry, W. A., Technical Note WCRT 54-181 (November 15, 1954).
3. Taylor, et al., WADC Technical Report 53-12 (March 1952).
4. Backer, G., Textile Research Journal, 21, (10) (1951).

Chairman Backer: The next paper will be given by Mr. R. C. Pike of the Textiles Fibers Department of the duPont Company. The title of his talk is New Fibers and Fabrics for Coating.

NEW FIBERS AND FABRICS FOR COATING

REXFORD C. PIKE -- Graduated from the University of Missouri in 1950 with a B. S. in Chemical Engineering. He is a Technical Representative with the Textile Fibers Department of E. I. duPont de Nemours and Company and has been employed by that Company for eight years. Mr. Pike started with the Company at the Seaford Nylon Plant supervising manufacturing operations. Four years ago he was transferred to his present assignment and currently specializes in the use of duPont fibers as substrates for coated fabrics. He served four and one-half years as a radio operator in the U. S. Navy.

Many fibers may be used as reinforcing membranes by the coating industry. These fibers include jute, cotton, regenerated cellulose, such as viscose rayon, and many more. Within the last two decades, the commercial availability of nylon and "Dacron" polyester fiber has enabled the coater to produce lighter, but stronger, fabrics to meet the increasing demand for products of this type. The coated fabrics business is quite diverse, and such diversity places constant pressure on fiber manufacturers to produce new fibers or to make improvements on existing ones that will meet the exacting specifications of the consumer.

Today I would like to discuss four such fibers and a new fabric principle. The first is a modification of existing nylon identified as Type 105, 205, or 305. A second fiber is a standard one but is new to the coating business in general -- Type 51 "Dacron". A third product is hot-stretched, heat-set Type 51 "Dacron". The fourth is "Teflon" TFE-fluorocarbon fiber. The new principle concerns use of synthetic fiber papers for coated products.

The first of these fibers is an improvement on our regular high tenacity Type 300 nylon and has been designated Type 305 nylon. This fiber is an improved zero-twist multifilament weaving yarn which has more uniform shrinkage throughout the supply package and exhibits less shrinkage and more uniform shrinkage during weaving and subsequent coating. Through its use a coated fabric is produced with fewer puckers.

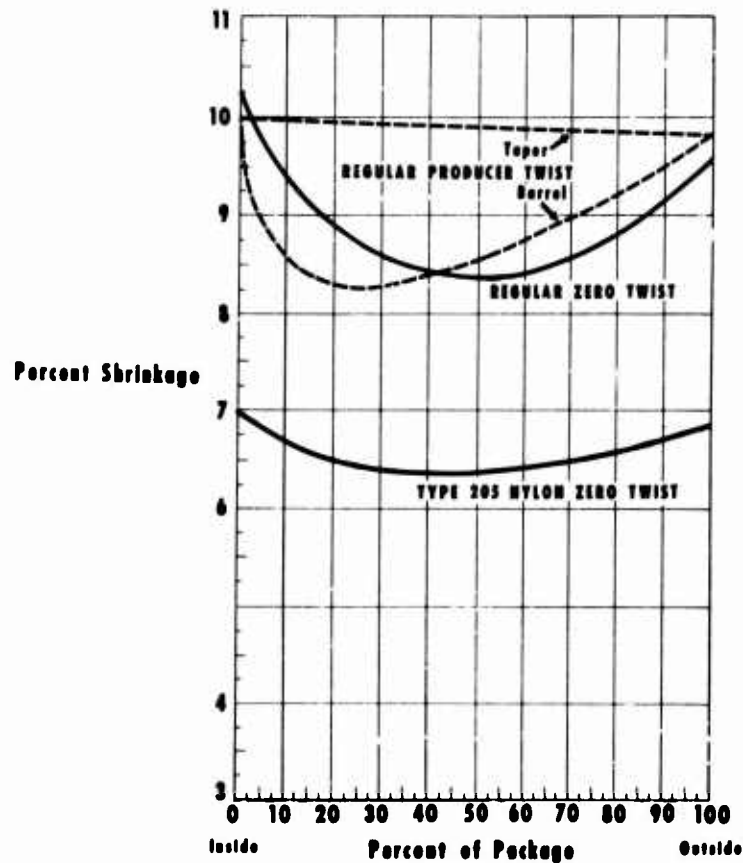


Fig. 1. Shrinkage profiles of duPont's new type 205 nylon and regular type 200 nylon.

Fig. 1 presents a comparison between the shrinkage profiles of regular 70-34-200 nylon, both zero twist and 1/2 turn Z, with Type 205 nylon. Here, a plot of percentage shrinkage on the

ordinate versus percentage of package (from the inside to the outside) on the abscissa shows an initial shrinkage of regular producer twist half turn yarn of about 10%. Note that the taper portion of the package maintains reasonably constant shrinkage. The barrel portion, however, falls off to a level of about 8% when one-fifth of the yarn remains on the supply package, then the shrinkage increases to 10% as the remainder of the yarn is consumed. By contrast, regular Type 200 zero twist shows a more uniform shrinkage, but the profile still is parabolic in shape, varying from 10% down to about 8% in the middle of the package, then back to 10% as the yarn is used. Type 205 nylon gives a flatter curve with less initial shrinkage, about 7% varying to 6 1/2% in the middle of the package, then with shrinkage increasing to 7% as the yarn is consumed. Although these curves are for 70 denier yarn, similar performance may be expected of other deniers.

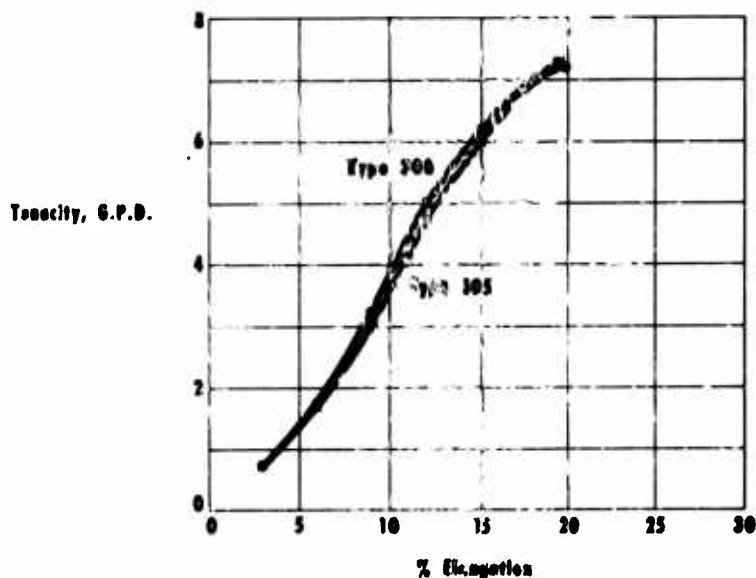


Fig. 2. Stress-strain properties of type 300 versus type 305 nylon.

Fig. 2 presents stress-strain curves for Type 300 and Type 305 nylon yarns. You will note that there is very little difference

between the characteristics of these two yarns.

What does this more uniform shrinkage mean in a coated fabric? First, for the weaver it eliminates pirn taper barre, reduces filling bands, and gives a more uniform width fabric. To the coater, it means producing a fabric with fewer puckers and of more uniform width and thickness.

Type 305, 210 denier nylon fabric has been successfully coated with both neoprene and vinyl compounds. Fig. 3 shows a "pucker count" comparison of neoprene coating on fabrics of Type 305 and

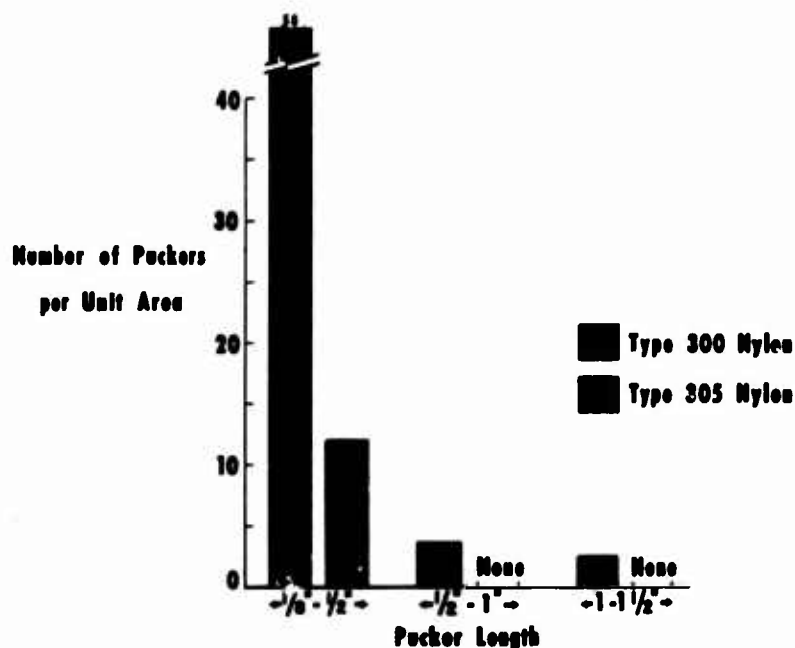


Fig. 3. Pucker count - neoprene coated.

Type 300 nylon. While it is difficult to apply numbers to the improvement in the finished coated fabric, this "pucker count" method gives an indication of what improvement may be expected. Here we have plotted the number of puckers per unit area (in this case, a square yard) on the ordinate versus the various pucker lengths on the abscissa. These are reported for three different length groupings of 1/8 to 1/2", 1/2 to 1", and for 1 to 1 1/2".

Note the marked improvement of the coated fabric of Type 305 nylon, particularly in the shortest puckers, where 58 were counted for the Type 300 and 12 for the Type 305.

Fig. 4 presents a similar comparison for these two base fabrics when coated with vinyl compound. Here less difference will be noted. We are not positive why this occurs, but it may be explained by the fact that since higher curing temperatures are used

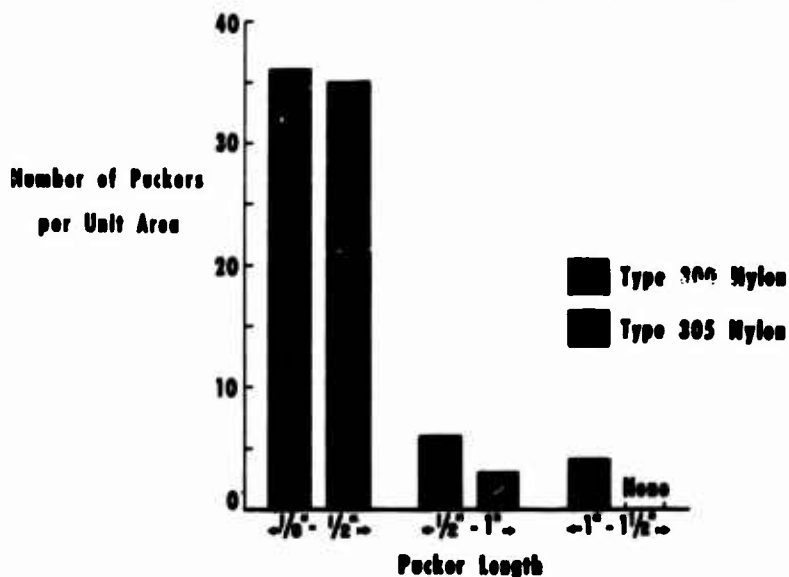


Fig. 4. Pucker count - vinyl coated.

with vinyl than with neoprene, internal yarn and fabric stresses are relieved by this higher heat level. This thought is partially borne out by the higher shrinkage encountered with vinyl when two identical base fabrics are coated with these two compounds. The best way to show the improvement using this yarn is by visual inspection of the two fabrics. Fig. 5 is a photograph of the neoprene fabrics just discussed. Note the improvement in the appearance of the Type 305 nylon fabric. At present, yarns are available in 70 and 140 denier Type 205, 200 denier Type 105, and 210 denier Type 305. Other counts can be considered as the need arises.



Fig. 5.

Another candidate for the coating industry is "Dacron". Two types will be considered here. The first, Type 51, is a high tenacity yarn and is commercially available. This fiber ranks high in initial modulus, has good transverse properties and excellent resistance to degradation from acids, and has the ability to withstand considerable shock loading without breaking. Fig. 6 presents a stress-strain curve for this "Dacron" yarn, both gray and boiled off, with the curve for Type 305 nylon yarn added for comparison purposes. Note the steep slope of the curve for the gray yarn, denoting high initial modulus for "Dacron". Also note the

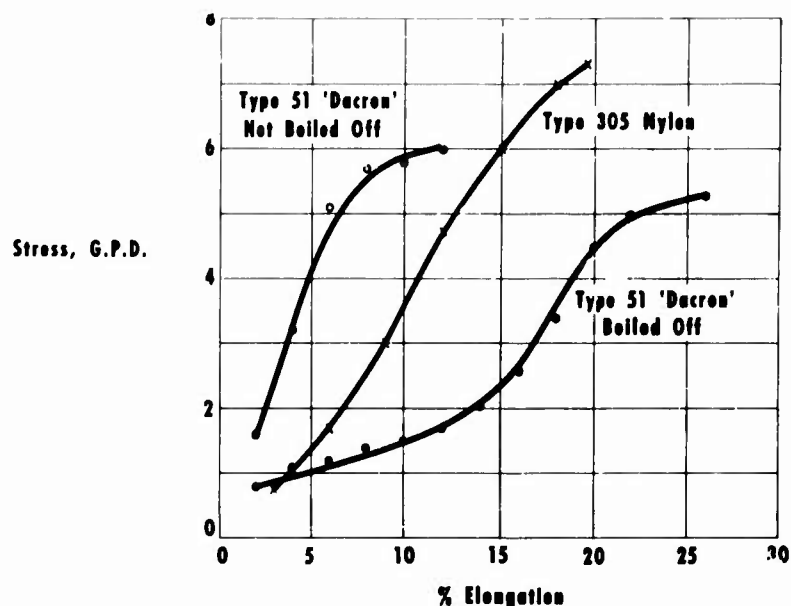


Fig. 6. Stress-strain curve for "Dacron".

ability of this yarn to elongate, even with this high modulus, to 12% before breaking. As might be expected, the boiled off yarn has a lower initial modulus and greater elongation. "Dacron" is dimensionally stable in the presence of moisture. It has a moisture regain at 75°F and 65% relative humidity of 0.4% as compared to 4% for nylon and 13% for rayon. Fig. 7 demonstrates this stability by comparing the growth of unit fiber length of boiled off nylon and "Dacron" when exposed in humidities from zero to 100%. Nylon grows almost 3%, while "Dacron" shows a growth of 0.1%. As you can see, the phenomenon is reversible. Fabrics of Type 51 "Dacron" have been successfully coated with neoprene, "Hypalon" chlorosulfonated polyethylene, and vinyl compounds.

The third yarn form suitable for coating is hot-stretched, heat-set Type 51 "Dacron". In certain special applications for coated fabrics, there has been a need to obtain maximum dimensional stability and a very low order of stretch or elongation in a structure

or shelter. Probably the first place where a real effort was made to obtain these properties was in a lightweight, single ply Air Force

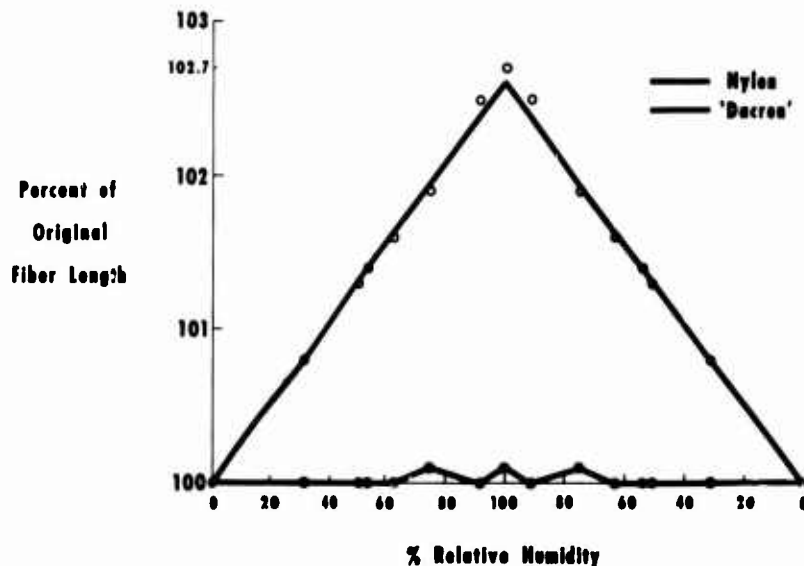


Fig. 7. Moisture stability of nylon and "Dacron".

radome, which was developed under contract by DeBell & Richardson Company, Hazardville, Connecticut, in a program begun two or three years ago. Here principles were developed along the lines of hot-stretching and heat-setting plied Dacron yarns and then weaving these into fabrics for coating.

"Dacron" yarns inherently have high modulus, particularly at loads up to 20 or 30% of the breaking strength. Hot-stretching and heat-setting of these yarns under conditions of elevated temperature and related levels of stretch can result in an even higher modulus, while reducing elongation to a low level. For example, Table 1 demonstrates typical "before and after" properties of two ply 1100 denier cord of "Dacron" subjected to a standard hot-stretching and heat-setting procedure. Note, that although there is essentially no difference in the breaking strength of the cord, the modulus has increased almost threefold, from 31

to 82; the tenacity, due to the change in denier, has increased a little, from 5.45 to 5.81; the elongation both at break and under a 10-pound load has shown a definite decrease, one-third in the case of breaking elongation and one-half under the 10-pound load. These data are not intended to represent an actual yarn for a base fabric but rather to demonstrate the type of properties that can be realized through hot-stretching and heat-setting.

TABLE 1
PROPERTIES OF CORDS OF HOT-STRETCHED
AND HEAT-SET "DACRON" (1100/2)

	<u>Gray</u>	<u>Stretched 8%</u>
Initial modulus, grams per denier	31	81.8
Breaking strength, lb	29.3	28.3
Tenacity, grams per denier	5.45	5.81
Percentage elongation at break	14.7	9.5
Percentage elongation at 10 pounds stress	6.5	3.0

Now, quite logically, one will ask what the significance of the use of hot-stretched and heat-set yarns is to fabric properties. Referring again to the Air Force development work, one typical fabric woven from plied hot-stretched and heat-set "Dacron" yarns has the physical properties shown in Table 2. As you can see, the yarns used were three ply 220 denier Type 51 "Dacron" hot-stretched and heat-set to 206 denier. The tenacity reported was a phenomenal eight grams per denier, with a breaking elongation of less than 16%. Its grab tensile strength was quite high, reported at 465 lb in the warp and 400 lb in the filling.

With proper hot-stretching and heat-setting, it appears feasible to thermally stabilize the yarns prior to weaving in such a manner that the woven cloth can be coated and cured with compounds such as neoprene, "Hypalon", or vinyl, producing a fabric with high strength and extremely low elongation at break. Further, utilizing these yarns we have been able to demonstrate that the coating of

TABLE 2
 PROPERTIES OF HOT-STRETCHED AND HEAT-SET
 FABRIC OF "DACRON"

Yarns	3 ply, 220 denier, Type 51 "Dacron" hot-stretched and heat-set to 206 denier
Tenacity	8 grams/denier
Fabric weave	2 x 2 basket
Fabric count	45 x 45
Fabric weight	7.5 oz/yd ²
Fabric strength warp and filling	465 x 400
Fabric elongation	15.6

gray fabric off the loom, assuming proper predipping with materials such as isocyanates, appears feasible and offers adequate coating adhesion properties and proper appearance of the coated and cured cloth. In brief, it appears possible to thermally stabilize a yarn and, hence, obviate the necessity of finishing and/or fabric heat-setting steps before coating. Such a product is available from several concerns.

Another fiber for coating is "Teflon". The fiber is spun from its resin form and retains the unusual chemical and heat resistant properties of the resin. It is brown in color and is one of the most chemically resistant fibers known. Table 3 illustrates its physical properties. Note in particular, its high density of 2.3 gm/cc and its useful environmental temperature of -100 to 525°F. The only substances that are known to react with "Teflon" are alkali metals, fluorine gas at high pressure and temperature, and chlorine trifluoride. The only known solvents are fluorinated organic liquids at temperatures above 570°F. It absorbs no moisture, has an extremely low coefficient of fiber to fiber friction, and has a very low level of adhesiveness.

TABLE 3
PROPERTIES OF "TEFLON"

Color	Brown
Density	2.3 gm/cc
Breaking tenacity	1.6 gm/denier, at 70°F
Elongation at break	13% at 70°F
Initial modulus	16.0 gm/denier
Useful environmental temperature	-100 to 525°F
Zero strength temperature	590°F
Moisture absorption	0%
Wettability	Most non-wettable of all fibers
Coefficient of fiber to fiber friction	About 0.2 - lowest of all known fibers

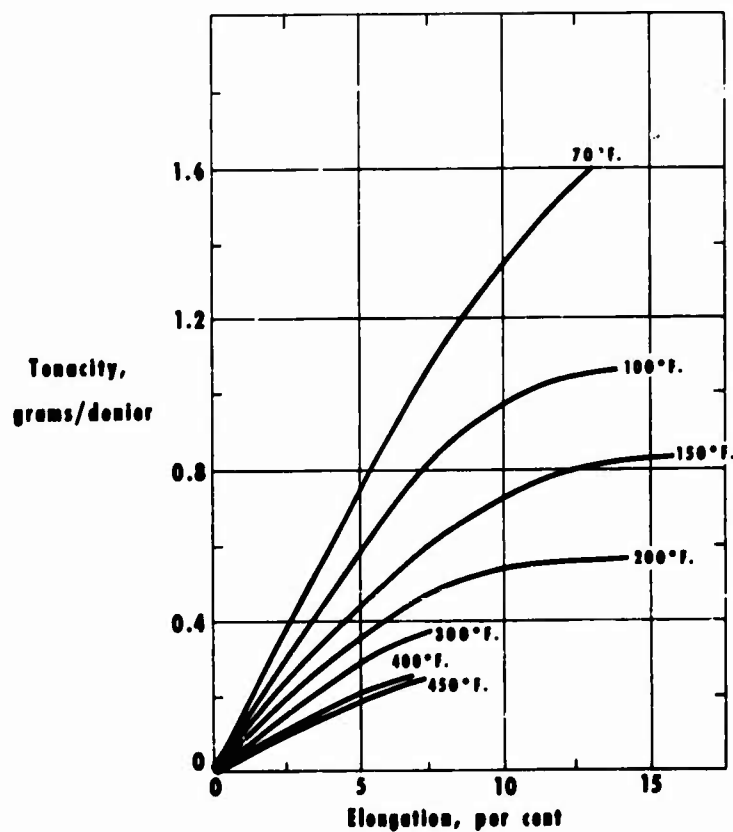
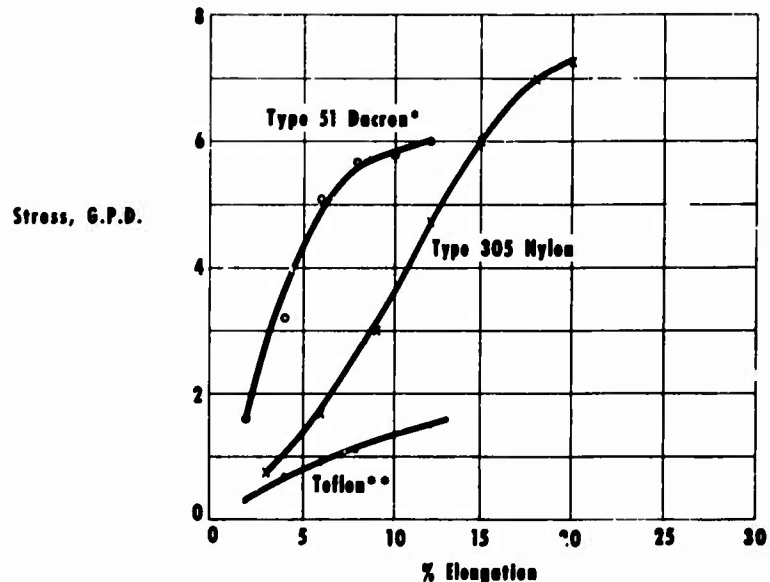


Fig. 8. Stress-strain properties of "Teflon" yarn at various temperatures.

Fig. 8 shows a stress-strain curve for this yarn and how it reacts at various temperatures. It has rather low initial modulus at all temperatures, with elongations remaining essentially constant at about 13% up to the 200°F level, then falling off to about half of that through 450°F. Fig. 9 presents a stress-strain curve of



*Du Pont's registered trademark for its polyester fiber
 **Du Pont's registered trademark for its TFE-fluorocarbon fiber

Fig. 9. Stress-strain curves.

"Teflon" fiber at standard conditions of 70°F and 65% relative humidity in comparison with the previously discussed fibers, Type 305 nylon and Type 51 "Dacron".

"Teflon" fiber is classed as nonflammable, decomposing rather than melting, although it does soften at high temperatures. In some applications this can be tolerated because of the fiber's excellent retention of tensile properties after prolonged exposure. Fig. 10 demonstrates this stability. Since shrinkage of the fabric did occur, the data were corrected to the original warp and count before exposure. After 192 hours' exposure at 500°F, this twill fabric has lost approximately 8% of its strength; conditions under which most other fibers would have been reduced to a useless char.

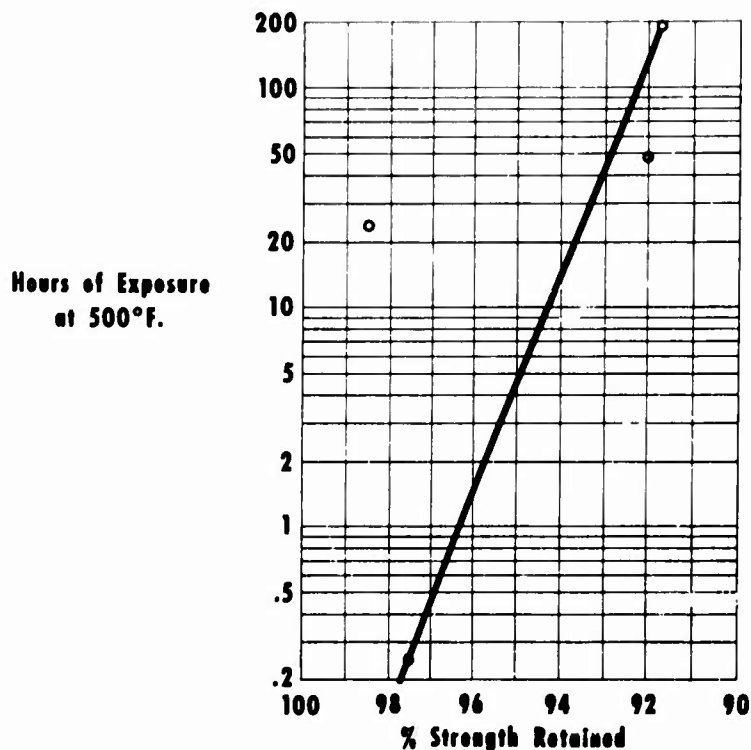


Fig. 10. Effect of exposure at 500°F on the tensile strength of fabric of "Teflon".

Fabrics were allowed to come to equilibrium at standard conditions of 70°F, 65% relative humidity before testing.

Fabrics of "Teflon" have been coated with the neoprenes, silicone rubbers, and "Viton A" synthetic rubber. Table 4 shows the performance of a fabric of "Teflon" coated with "Viton A" and exposed to air at 400°F. Using a glass fabric as a control, the structure of "Teflon" and "Viton A" performs well at the 60-day exposure level, as indicated by the low decrease in tear strength.

Table 5 presents similar data, differing in that the exposure was made at 500°F. In this case, something occurred with the structure of "Teflon" and "Viton A", causing it to increase in tear strength. We cannot offer any reasonable explanation for this increase.

TABLE 4
EFFECT OF TEMPERATURE ON FABRICS OF "TEFLON" AND GLASS
WHEN COATED WITH "VITON-A" SYNTHETIC RUBBER

<u>400°F</u>		
<u>Length of exposure, days</u>	<u>Tear strength retained, lb.</u>	
	<u>Teflon</u>	<u>Glass</u>
Original	16 x 13	2 x 3
28	15 x 11.5	2 x 3
60	15 x 11.5	2 x 3

TABLE 5
EFFECT OF TEMPERATURE ON FABRICS OF "TEFLON" AND GLASS
WHEN COATED WITH "VITON-A" SYNTHETIC RUBBER

<u>500°F</u>		
<u>Length of exposure, days</u>	<u>Tear strength retained, lb.</u>	
	<u>Teflon</u>	<u>Glass</u>
Original	16 x 13	2 x 3
14	35 x 17	2 x 3
28	25 x 19	2 x 3
60	22 x 22	2 x 3

Since "Teflon" has a very low coefficient of fiber to fiber friction value, adhesion must be obtained by mechanically napping the fabric surface. Table 6 shows the relative performance of fabrics of the fiber with and without napping. The first example of adhering "Teflon" to steel, using a commercial adhesive system, brought about a tenfold improvement; the second example of an untreated fabric of "Teflon", cured to rubber, effected an eightfold improvement. Fig. 11, in magnification, shows the appearance of an identical fabric with and without napping. Note how the weave pattern is obscured, an indication of a good job of napping.

TABLE 6
ADHESION OF UNTREATED AND NAPPED FABRICS OF "TEFLON"

<u>Fabric description</u>	<u>Adhesive</u>	<u>Bonded to</u>	<u>Peel strength lb/in.</u>
1. Untreated fabric	Permacel* #18	Steel	1
2. Napped fabric	Permacel #18	Steel	10
3. Untreated fabric	None	Cured to rubber	1
4. Napped fabric	None	Cured to rubber	8

* Registered trademark of Permacel Le Pages, Inc., New Brunswick, N. J.



Fig. 11.

The fifth fiber product for consideration is synthetic fiber paper. These papers have been made experimentally by substituting nylon, "Dacron", or "Orlon" acrylic fiber in place of the wood pulp or rag stock usually used. These papers may be made of 100% synthetic fibers. Table 7 shows the physical property level which may be expected of papers made in this fashion. For comparison, data on a Kraft paper and a woven cotton fabric are included. Note that the tensile strength figures have been unitized; that is, reduced to lb/in./oz/yd². With this technique the approximate tensile strength may be determined for any paper, depending on its base weight. Both nylon and "Dacron" perform well in tensile strength as is indicated by the 16.8 and 13.7 lb, respectively. Note that the two control structures perform at about the 10-pound level. The breaking elongations are higher for the synthetic fiber paper, denoting the ability of these structures to readily absorb shock loads. The initial resistance to elongation, particularly for the paper of "Dacron", is very good and will resist deformation under low loads.

The Elmendorf tear strength of the synthetic fiber papers is not as high as the cotton control, although the nylon paper approaches it for all practical purposes. All the papers made from synthetic fibers are much better than the Kraft control.

In fold endurance, nylon and "Dacron" give a good amount of themselves when compared to cotton, and all synthetic fiber papers exceed the performance turned in by the Kraft.

Synthetic fiber papers allow a smoother coating of vinyl to be applied since there is no weave pattern to be obscured. For this same reason, coated synthetic fiber papers are easily embossed. This uniformity of product produces excellent dielectric seaming properties.

TABLE 7
PHYSICAL PROPERTIES OF SYNTHETIC FIBER PAPERS

Fiber	Tensile ² lb/in./oz/yd ² , dry 21°C	Tensile ² lb/in./oz/yd ² , Wet 21°C	Break %, elong.,	Tongue tear strength lb/oz/yd ²	MIT fold endurance cycles
100% Nylon 1/4" 3 denier	16.8	9.3	44	0.90	200,000
100% "Dacron" 1/4" 3 denier	13.7	11.0	30	0.58	185,000
100% "Orlon" 1/4" 3 denier	8.3	4.1	25	0.25	1,800
Woven Cotton	10.5	--	23	1.17	200,000
Kraft	10.0	0.45	6	0.12	750

In addition to 100% synthetics, nylon, "Dacron", and "Orlon" may be blended with other products such as rayon, sisal, and wood pulp, choosing in these cases a resin binder compatible with both components. Some recent development work, aimed at substrates for side panels in automobiles, involved a paper containing 50% "Dacron" and 50% wood pulp joined with a nitrile rubber binder. Table 8 outlines the physical properties of two different weight papers of "Dacron" and wood pulp as compared to 100% Kraft.

TABLE 8
PHYSICAL PROPERTIES OF UNCOATED SUBSTRATE PAPERS

<u>Description</u>	No. 1 <u>"Dacron"/</u> <u>Wood Pulp</u>	No. 2 <u>"Dacron"/</u> <u>Wood Pulp</u>	<u>Saturated</u> <u>Kraft</u>
Percentage blend	50/50	50/50	100% Kraft
Binder type	Hycar	Hycar	SBR
Total weight, oz/yd ²	2.9	3.5	3.0
1" Strip tensile, lb	19/23	21/17	4.2
Strip tensile, lb/in./oz/yd ²	6.5/7.9	5.7/4.9	1.3/0.66
Tongue tear, lb	1.2/1.8	0.8/1.5	0.5/0.5
Tensile, 150°F, 1 week, lb	16	22	18
Tensile, 150°F, 1 week, lb/in./oz/yd ²	5.5	6.3	6.0
Shrinkage (Ford), 1/2 Hour, %	--	+0.2/+0.4	-1.4/0.0
Shrinkage (Ford), 24 Hours, %	--	+0.2/+0.1	+0.8/+0.8

The only essential difference between these two papers of "Dacron" is the weight. With these papers, "Hycar" nitrile rubber is used as the binder, while the Kraft paper uses SBR-type rubber. The two weights of papers blended of "Dacron" and wood pulp are 2.9 and 3.5 oz/yd², compared to 3.0 oz/yd² for the Kraft. One-inch strip tensile test records 19 lb in the machine direction versus 23 lb in the cross direction for the lightest paper of "Dacron", 21 and 17 lb for the heavier, and 4- and 2-pound readings for the Kraft. Unitizing these figures on the basis of weight, the lighter paper blend of "Dacron" and wood pulp gives figures of about 7 lb in each direction, the heavier weight about 6 x 5, and the saturated Kraft

about 1 lb in each direction. Tongue tears for the two papers of "Dacron" are about 1 x 2 and 1 x 1 1/2, compared to the 1/2 lb in each direction for the Kraft. After exposure at 150°F for one week, the one-inch strip tensile remains at 16 and 22 lb for the two papers of "Dacron" and wood pulp, whereas the saturated Kraft has grown from 4 lb to 18 lb. Utilizing these figures, we can see that the three substrates perform about equally as well. The Ford Motor Company shrinkage test, for which we have no figures for the lightweight paper, shows a slight growth at both the half-hour and 24-hour levels for the heavier paper of "Dacron", compared to a slight contraction in the machine direction for the Kraft paper and no change in the cross direction after half an hour, then a substantial growth of almost 1% after 24 hours' exposure.

Table 9 compares physical properties for the same substrates when coated with vinyl. For reference, the substrate weights are

TABLE 9

PHYSICAL PROPERTIES OF COATED FABRICS

<u>Description</u>	No. 1 "Dacron"/ Wood Pulp	No. 2 "Dacron"/ Wood Pulp	Saturated Kraft
Substrate weight, oz/yd ²	2.9	3.5	3.0
Total weight, oz/yd ²	10.2	12.0	10.7
Scrub, back	150	450	75
Tensile, 1" strip, lb	21/21	23/23	16/11
Tear, Elmendorf Scale	21/16	23/17	32/19
Tensile, 1", 150°F, 1 week	20/19	23/17	15/11
Shrinkage (Ford), 1/2 Hour, %	0/0	0/+0.2	+0.4/-1.0
Shrinkage (Ford), 24 Hours, %	+0.4/+0.3	+0.2/+0.2	+0.1/+0.4

listed. Total weight of the three candidates are as you see -- 10.2, 12, and 10.7 oz/yd², respectively. A scrub test on the back of these papers shows the two synthetic fiber blend papers to perform substantially better than the Kraft paper used for control. In tensile properties, the paper blends of "Dacron" and wood pulp top off at about 22 lb in both directions, compared to 16 x 11

for the control. In Elmendorf tear, both the synthetic blend papers give a reading of only about two-thirds that of the Kraft. After exposure at 150°F for one week, samples retained essentially all of their original strength. Exposure to shrinkage conditions, using the Ford shrinkage test, showed very little change for the two blend papers after half an hour; there was a positive increase in the machine direction and a shrinkage in the cross direction for the Kraft paper. After 24 hours, all papers showed an increase in growth in both directions although the synthetic blend papers were more dimensionally stable.

On a performance basis, these paper blends of "Dacron" will outperform the Kraft papers at the same or less cost, provided the thickness of the final structure is not critical. In most cases, adjustments must be made to existing dielectric seaming machines, where a lighter weight synthetic paper based substrate is used. Development programs are under way to bring forth synthetic fiber papers through regular channels to the point of commercialization in the not too distant future.

In summary, we believe the five products discussed -- Type 305 nylon, regular Type 51 "Dacron", hot-stretched, heat-set Type 51 "Dacron", "Teflon" fiber, and synthetic fiber papers -- are excellent candidates as substrate materials for coated fabrics. We hope we have stirred your interest in possible areas where such products may be used.

TECHNICAL SESSION NO. 3

George Thomas, presiding

Chairman Thomas: The first speaker this morning is a young man who is with the duPont Company. I had the pleasure of visiting Mr. Fritz in his laboratories at Wilmington a short while ago and we had a long technical debate. I was more than impressed because for each of his conclusions Mr. Fritz had at least fifty pages of data. I think that this morning you are going to hear a man who is summarizing anywhere from five to one hundred pages of data per minute in his address. I think you will hear a well worthwhile and well-prepared speech from Mr. F. H. Fritz. He is a division head in the Elastomer Chemicals Department of the duPont Company. Mr. Fritz will talk on the Technical Advancement in Coating Materials for Fabrics.

TECHNICAL ADVANCES IN COATING MATERIALS FOR FABRICS

F. H. FRITZ -- Graduated from Bucknell University in 1943 with a B. S. in Chemical Engineering. The first few years after graduation were spent with the Firestone Tire and Rubber Company in technical development activities involving mechanical rubber products. For the last ten years Mr. Fritz has been employed by the duPont Company in various technical and sales assignments concerning the Company's sales to the rubber industry. He is presently a division head in duPont's Elastomer Chemicals Department in charge of development and technical service activities in the field of mechanical goods and coated fabrics.

The combination of polymeric coatings and textiles provides a host of materials vital to the operation of our military forces. Generally, coated fabrics are employed either to contain gases

(as in blimps) or to protect other materials from the elements or other deteriorating influence (as in tarpaulins or radomes). The fabric is the strength member, imparting toughness and snag or tear resistance to the construction. The coating protects the fabric from deterioration and, properly chosen, provides an impermeable barrier resisting the penetration of fluids (gases or liquid).

Previous papers have reviewed the present and future military requirements for coated fabrics. Others have summarized the recent improvements in textiles and in weaving techniques. In this paper the advances made in rubber and plastics coatings during the past twenty-five years, together with new materials and methods of fabrication that are on the horizon for the coated fabrics industry, will be discussed.

Some of the major technical requirements for military coating materials on fabrics are as follows:

1. Toughness -- resist abrasive wear and snagging or tearing.
2. Lightness of weight and flexibility -- for ease of handling.
3. Resistance to degradation and protection of the fabric after long periods of outdoor exposure.
4. Freedom from mildew and fungus attack in tropical climates.
5. Retention of flexibility in tropical heat or under severe Arctic conditions.
6. Impermeability to gases and water. In some applications, such as rainwear, the coatings must be "breathable" and permit the passage of water vapors.
7. Flame resistance.
8. Extreme resistance to elevated temperatures and to a wide variety of chemical media in specific uses as diaphragms or protective clothing.

9. Ease of manufacture. It must be possible to fabricate complex assemblies (i.e., radomes, life jackets, pontoons) quickly and simply often under difficult conditions.

From this brief analysis it is obvious that without the introduction of man-made rubbers and plastics into the coated fabrics field many of the above properties would be merely theoretical specifications of the designer rather than the realities of today's products. No one polymer, either elastomer or plastic, combines all of the characteristics desired of a coating material. While synthetic polymers have a wide range of basic properties, the usefulness of these products can be increased even further by compounding. Thus, it is important that the consumer of coated fabrics accurately specifies the requirements of a particular application so that the manufacturer can compound the coating material judiciously to fit that set of properties.

Polymers in Major Commercial Use. With these facts in mind the discussion in the following paragraphs is designed to catalogue some of the more important basic properties of widely-used coating materials for fabrics into relative positions of usefulness. In certain cases, order of magnitude comparisons are made because of lack of specific test data. However, such comparisons are reinforced by industrial experience.

"Natural rubber" has been used as a coating material since the origin of the proofed goods industry. Its vulcanizates are tough, quite colorable, and have outstanding low-temperature flexibility. However, natural rubber weathers poorly, is quite sensitive to mildew and fungus growth, and burns readily. While these drawbacks can be minimized by compounding, the advent of other polymers has relegated natural rubber to a position of lesser importance in this field.

"Butadiene-styrene copolymers (SBR)" reached commercial importance as coating materials during World War II as a replacement for natural rubber, which was then in short supply. For all practical purposes SBR has the same general properties as natural rubber; that is, good toughness, colorability, and outstanding low-temperature flexibility but poor resistance to weathering, flame, and fungus growth.

"Polyisobutylene rubbers (butyl)" are polymers of low chemical unsaturation and therefore are quite stable to oxidizing influences. The maximum unsaturation of the polymer is 2.5 mole per cent as compared to 100 mole per cent for natural rubber; thus, as would be expected, butyl rubber's resistance to ozone degradation and to outdoor weathering is markedly superior to natural rubber.

Low gas permeability, butyl's most outstanding property coupled with its good resistance to oxidation, has been the basis of its technical acceptance as a coating material for fabrics. In addition, butyl rubber has adequate strength and good low-temperature flexibility. Its resistance to attack by mildew and fungus is superior to natural rubber, but it has about the same degree of flame resistance. Polar liquids such as alcohols, ketones, esters, and glycols have little or no solvent action on butyl rubber. Mineral acids and vegetable or animal oils exert little degrading effect; however, most hydrocarbon solvents exhibit a strong swelling action on butyl rubber vulcanizates. Halogen gases and hydrogen sulfide under certain conditions cause excessive degradation.

"Butadiene-acrylonitrile copolymers (Buna N)" have been of limited interest in coated fabrics markets. They are characterized as having excellent resistance to hydrocarbon solvents which would indicate their use in coated fabric diaphragms, protective clothing, and other areas. The degree of solvent resistance is directly proportional to the amount of acrylonitrile in the copolymer mixture

while the low-temperature flexibility is an inverse function. Buna N coatings have good toughness and abrasion resistance, considerably lower gas permeation than natural rubber, but only fair resistance to burning and to degradation upon outdoor weathering.

Even though the nitriles, as well as SBP, are not classified as weather resistant, they afford protection to fabrics in those services where outdoor exposure is rarely, if ever, involved. Then, too, the use of chemical antioxidants has improved the general ozone resistance of these elastomers so that their protective level on fabrics can now be significantly higher than in the past. This is illustrated in Fig. 1, which compares the ozone resistance of

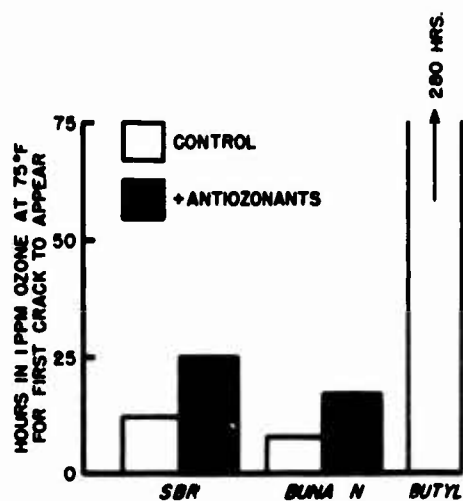


Fig. 1. Effect of antiozonants.

typical SBR and nitrile vulcanizates with and without standard levels of chemical antioxidants. A weather-resistant butyl vulcanizate was used for control purposes.

Blends of Buna N rubbers with polyvinyl chloride (PVC) offer an interesting combination of properties for coated fabrics. The PVC greatly improves the weatherability and flame resistance of the composition while not detracting from the solvent resistance of the Buna N. Light-colored compositions withstand moderate levels of ultra-violet light and ozone without degrading but tend to become stiff after long periods of exposure. By and large the low-temperature properties of such blends are marginal for Arctic service.

"Polychloroprene rubbers (neoprene)" have a good balance of properties and have been widely used in coated fabrics applications. Neoprene coatings are quite stable to deterioration from weathering and ozone, although they will discolor in sunlight. They have good abrasion resistance and do not support combustion. Their gas permeation is intermediate between butyl and rubber. Although certain forms of neoprene crystallize or stiffen at moderately low temperatures, the compositions used in coatings are flexible and otherwise serviceable under most extremes of Arctic conditions. In addition, neoprene has good resistance to many types of liquids including dilute acids and bases, hydrocarbons, and to elevated temperature exposure.

"Polyvinyl chloride (PVC)" represents the thermoplastic polymers first major contribution to the coated fabrics field. Among its other technical strong points, PVC-coated fabrics can be prepared more simply than those of vulcanizable elastomers and can be heat sealed when fabricating complex products eliminating the more cumbersome and time-consuming adhesive bonding or stitching processes. PVC, when properly compounded and stabilized, can be obtained in a wide range of colors and is very resistant to degradation from ozone or ultra-violet light. It resists burning (in fact, melts upon exposure to flame). PVC is also relatively insensitive to fungus growth providing the proper plasticizers are used in the formulation. Its abrasion resistance is excellent. However, PVC-coated fabrics generally stiffen at moderately low temperatures and thus must be carefully evaluated for use under Arctic conditions.

"Polyvinyl butyral (PVB) resins", also thermoplastic in nature, have found specialized but large-scale application in rainwear. PVB coatings of less than one mil thickness provide excellent clarity, toughness, and waterproofness to the garment. Generally speaking, however, they provide little ultra-violet light protection to the fabric which thus limits their usefulness considerably.

TABLE 1
CHARACTERISTICS OF CONVENTIONAL COATING MATERIALS

Polymer	Toughness & Abrasion Resistance	Ease of Fabrication	Low Temperature Flexibility	Stability at Elevated Temps.	Resistance to Burning	Resistance to Mildew & Fungus	Impermeability to Gases	Weathering Characteristics	Colorability
Natural Rubber	Good	Good	Excellent	Fair	Poor	Poor	Poor	Poor	Good
SBR	Good	Good	Excellent	Good	Poor	Poor	Poor	Poor	Good
Butyl	Fair	Fair	Very Good	Very Good	Poor	Good	Very Good	Good	Fair-Good
Neoprene	Good	Good	Good	Good	Very Good	Very Good	Good	Very Good	Fair
Polyvinyl Chloride	Good	Excellent	Poor	Poor	Very Good	Very Good	Very Good	Good	Very Good
Polyvinyl Butyral	Good	Excellent	Poor	Poor	Good	Very Good	Very Good	Poor	Very Good
Buna N	Good	Fair	Fair	Good	Poor	Poor	Very Good	Poor	Fair-Good

Table 1 characterizes the polymers discussed above and can be broadly used to ascertain the suitability of a coating for specific services. With so many different coating materials available today the manufacturer and consumer, on the one hand, have fine opportunities to design products that fulfill a particular set of requirements completely. On the other hand, their choice of the best coating material can be a very difficult one, particularly if both parties do not have a good grasp of the relative merits of each polymer class.

Design Criteria. Up to this point the basic properties of widely-used coating polymers have been discussed. However, in designing coated-fabric constructions, there are several major factors that generally influence the choice of coating material to a greater extent than the others mentioned earlier in this paper.

"Fabric Protection". Among the primary design problems is the determination of the minimum coating thickness that will properly protect fabrics upon outdoor exposure. This problem can be illustrated with the data in Fig. 2 which shows the effect of film

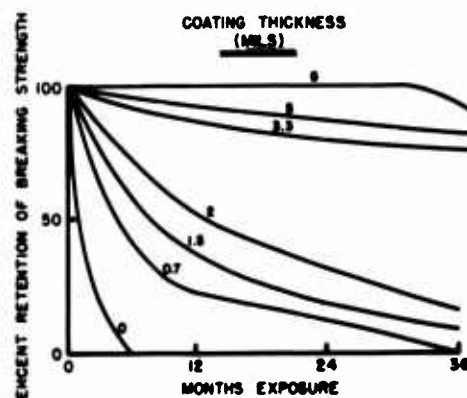


Fig. 2. Weathering of black neoprene coated nylon.

under less severe conditions, less than 4 mil could be considered quite adequate.

thickness on the strength of nylon fabrics coated with a black neoprene composition. It is quite evident that even very thin coatings offer positive protection to the nylon but that at least 4 mil are necessary on the exposed side for maximum long-term serviceability in direct sunlight. Of course,

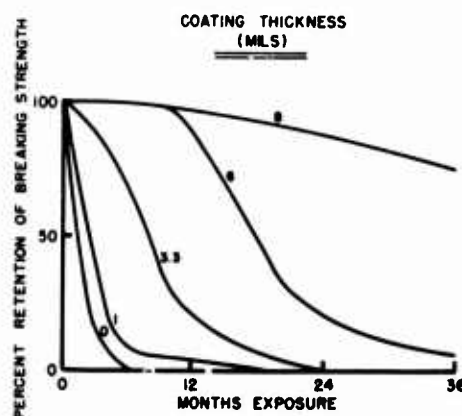


Fig. 3. Weathering of olive drab neoprene coated nylon.

Another factor in designing coated fabrics is the color of the coating. It is well known that many color pigments are not as effective screening agents for damaging light rays as is black. This can be seen by comparing the data in Figs. 2 and 3. From Fig. 3 it is evident that a minimum of 8 mil is necessary with an olive drab

color for adequate long-term serviceability.

Erosion of the surface by rain and wind is another important factor in designing coated fabrics. The amount of erosion is related to the chalking of the filler plus oxidation of the elastomer. It is obvious that compounding will have a major effect on this important property. Erosion measurements were made on the black and olive drab neoprene coatings discussed above. The olive drab coating eroded much more than the black neoprene. After three years in Florida the total thickness of each of the olive drab coated samples of 6.75 oz nylon had decreased 4 to 5 mil. This compared to a decrease of 0.5 to 1.5 mil for the black-coated 6.75 oz samples. Since practically all of the loss in thickness occurred in the exposed side, it is obvious in this case that olive drab coatings containing light-colored pigments must be about 4 mil thicker than black coatings to obtain equivalent weather protection over a three-year period.

While weather conditions may have a real effect on the polymeric coating, it is also necessary to consider how the coating

itself affects the strength of the supporting fabric. Of the general-purpose polymers widely used today, only three would be classified as truly weather resistant: neoprene, polyvinyl chloride, and butyl. Since two of the three are chlorine-bearing materials, the question of acid tendering of fabrics naturally arises. This is true especially when the fabrics are used under humid conditions. In the case of neoprene, even after many years of use, acid liberation has not been found to be a problem in properly formulated compositions. Even very thin coatings where the liberation might be aggravated due to ideal oxidative conditions have shown no evidence of tendering.

"Fungus and Mildew". Another problem that must be considered in designing coated fabrics is their resistance to fungi. It is well known that fungus attack of fabrics and coating materials has resulted in considerable loss of critical military goods over the years. The problem as related to fabrics, of course, varies with the textile -- some of the newer materials being quite resistant to degradation. The same is applicable with coatings; very few coating polymers provide nutrient value to fungus growth. On the other hand, relatively few are fungitoxic; that is, capable of retarding or killing fungus growth. The data in Table 2 illustrate the relative resistance to typical fungi of several coating polymers and the effect of chemical inhibitors.

In many cases chemical inhibitors are used to treat fungus-prone fabrics prior to coating. The Corps of Engineers recently concluded a study of the effect of various inhibitors in relation to the type of elastomer coating used on cotton. They found considerable unexplained variation in results. This led to the recommendation that the choice of treatment for elastomer-coated cotton fabrics should be made only on the basis of a thorough evaluation of each coated fabric construction en toto, rather than drawing

conclusions based upon the fungus resistance of individual components.

TABLE 2
FUNGUS RESISTANCE OF COATING POLYMERS*

Neoprene	No growth or germination
Natural rubber	Uniform and extensive growth
Natural rubber plus mold inhibitor	High inhibition - at 100x magnification only 1% of spores germinated
Buna N	Uniform and extensive growth
Buna N plus mold inhibitor	High inhibition

* Sprayed with mixed spore suspension of: *Penicillium digitatum*, *Aspergillus* sp., *Chaetomium globosum*, and *Stachybotrys* sp., and incubated in a moist chamber at 80°C for two months. The samples were then examined microscopically.

"Low-temperature Serviceability". Low-temperature performance is yet another important function of coated fabrics to be investigated by the designer. Considerable thought and experimental work have gone into the low-temperature testing of rubber-like materials. However, there are still many problems connected with specifying the proper test for the application. In the coated fabrics industry brittleness tests such as ASTM D 736 or D 746 are often used. To predict the stiffness (or ability to function as a flexible material) of the coating, torsional tests such as described in ASTM D 1043 or D 1053 are employed. Stiffening, known as "simple temperature effect", is characterized by changes in modulus and hardness. It takes place quickly -- as soon as thermal equilibrium is established. As the temperature of exposure is decreased to the lower ranges, another effect known as second order transition or embrittlement becomes apparent. It also takes place as soon as

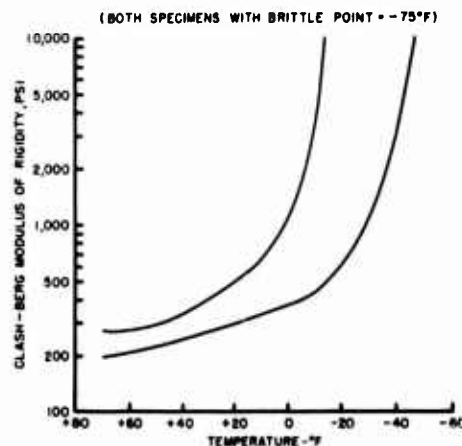


Fig. 4. Clash-berg stiffness vs. temperature.

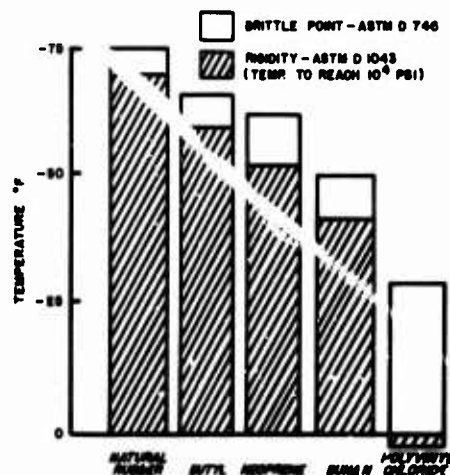


Fig. 5. Typical low temperature properties.

thickness of 5 mil is relatively flexible. Although for most military services a precise means of classifying coating materials for multitudes of services must be employed, some consideration of coating thickness would serve as a realistic yardstick of serviceability. Many of the general-purpose coating materials have good low-temperature properties as shown in Fig. 5 on the basis of both

thermal equilibrium is established. To predict relative stiffness at a given temperature on the basis of brittleness tests is open to considerable question. Oftentimes there is little correlation between the two. The difference in shape of the relative stiffness curves of two vulcanizates with the same brittle point in Fig. 4 illustrates this fact.

While the polymer and its compounding affect stiffness at low temperatures, the total coating thickness on the fabric will also alter the apparent modulus or stiffness of a coated fabric to a marked degree. For instance, a fabric with a coating thickness of 20 mil might not be considered functional at -20°F while the same material with a coating

brittle point and Clash-Berg modulus of rigidity. The values are typical of those obtainable with coating compositions of each polymer.

"Flame Resistance". Flame resistance is yet another design factor that has become a prime consideration in recent years. The presence of relatively large amounts of a halogen, such as chlorine, in a polymer molecule generally is associated with the property of flame resistance. For this reason, polymers such as PVC and neoprene have been widely used in coated fabrics which must resist combustion. Actually, flame resistance is a comparative term since almost all polymeric materials will ignite under the proper conditions. However, these halogenated polymers can be characterized as self-extinguishing, and the temperature at which they ignite has been shown to be higher than that of non-halogen bearing polymers as in Table 3. The data in Tables 3 and 4 were obtained using a new and quite accurate test method for measuring the combustibility of typical elastomer vulcanizates. Heat from an electric arc is focused on the test specimen by parabolic reflectors. Temperature is controlled by light filters and measured with a thermocouple. The time for a specimen to burn through and break has been found to be highly reproducible and an excellent index of flame resistance. Due to the high level of precision, even one second represents a significant difference in flame resistance.

TABLE 3
FLAME RESISTANCE OF RUBBER AND NEOPRENE

	<u>Natural Rubber</u>	<u>Neoprene</u>
Vapor ignition temperature, °C	150	250
Kindling temperature, °C	850	900
Breaking time at 900°C, sec	11	18
Flame propagation	Consumed	0

TABLE 4
FLAME RESISTANCE OF COATING POLYMERS

	Breaking time at 900°C, sec	Flame propagation
Natural Rubber	11	Consumed
SBR	12	Consumed
Butyl	12	Consumed
Neoprene	18	0
Polyvinyl chloride	16	Partly Consumed
Buna N	12	Consumed

"Gas Permeability". Gas permeability is another basic factor in designing such products as blimps, life vests, or pontoons. The permeation of gas through a polymer is a process in which molecules dissolve on one side of the membrane, diffuse through the film to the other side, and then evaporate from the membrane. The chemical and physical structure of the polymer -- the size, critical temperature, and polarity of the gas -- and the physical conditions during testing all result in wide variations in permeability. In general, crystalline materials have lower gas permeabilities than amorphous materials. Thus, elastomers (generally amorphous) are more permeable to gases than most plastics. However some of the synthetic rubbers (such as butyl) approach or equal the permeability of some of the best plastics due to the symmetry of the elastomer molecule and/or the polarity of its substituent groups. Typical permeability values for several common gases are shown in Table 5. The wide variation between polymers gives the designer great latitude in choosing the best material for a particular application.

Permeability of coated fabrics does not vary linearly with coating thickness. Construction of the fabric, the thread count, and number of plies affect gas permeability. Often the textile itself is the most important factor in obstructing gas loss through coated fabrics -- the coating serving merely to caulk the spaces between the threads.

TABLE 5

PERMEABILITY OF POLYMERS TO GASES

10^{-8} cc/cm²/thick/second/atmosphere,
25°C at 0% relative humidity

	<u>H₂</u>	<u>N₂</u>	<u>O₂</u>	<u>CO₂</u>	<u>He</u>	<u>CH₄</u>
Natural Rubber	37.4	6.1	17.7	99.6	23.7	22.0
SBR	23.7					
Butyl	4.6	Neg.	0.34	4.2	5.2	0.43
Neoprene	15.4	0.77	3.0	16.9	9.9	2.0
Polyvinyl chloride	1.5					
Buna N (32% AN)	9.0	0.46	1.78	14.1	7.5	--
Hypalon	8.2	0.68	1.6	12.0	5.5	1.3

Moisture vapor transmission, another facet of permeability, is an important comfort consideration in coated fabrics used as rainwear, tentage, and the like. Although there are several means for minimizing or controlling moisture condensation (breathing holes or chemically causing porosity in coatings), natural rubber continues to have one of the highest and therefore most desirable (for personal comfort) rates of water vapor transmission. This is shown in Table 6. On the other hand, several of the synthetics and plastics would be more suitable for those services where a complete moisture seal is desirable.

TABLE 6

WATER VAPOR TRANSMISSION

mg/in.²/24 hours at 75°F, 1 mil film

Natural Rubber	30
SBR	16
Butyl	0.6
Neoprene	10
Polyvinyl chloride	1 (Estimated)
Buna N	2 (Estimated)

New Polymers Available for Coating Fabrics. From the previous discussion it is evident that many polymers used as coating materials today extend the product life considerably over that

which could be obtained with natural rubber. Fortunately, as the technical requirements imposed by the military and by other consumer groups become more technically complex, the chemists have synthesized new polymers which keep pace with or even surpass the goals set forth.

"Chlorosulfonated polyethylene". One of these new materials is Hypalon, prepared by introducing sulfur and chlorine onto the polyethylene polymer chain. Among many general-purpose coating

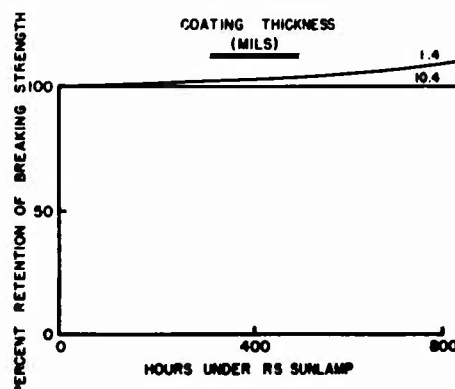


Fig. 6. Weathering of green hypalon coated cotton.

materials, Hypalon appears to have an excellent balance of weathering characteristics -- including retention of strength, lack of erosion or chalking, and permanence of colors. Preliminary data indicate that as little as 2 to 4 mil of white or light-colored Hypalon coatings over nylon, rayon, cotton, etc., are adequate for maxi-

imum long-term weather resistance. This is illustrated in Fig. 6. In addition, Hypalon coatings would be expected to exhibit the following properties:

1. Outstanding colorability -- from white through black. Although Hypalon is sensitive to certain chemical variations, coatings can be made that will maintain these colors over years of service outdoors. Little change took place in the original color of coatings which were exposed in Florida for four years. The strength of the coatings was also unchanged. These studies have indicated that coating life is probably dependent upon the rate of erosion. With Hypalon the rate of erosion has been found to

average 1/4 mil per year. Other studies have shown that this can be further reduced by using special compounding techniques to as little as 1/10 mil per year.

2. Very good resistance to abrasion. Typical comparisons of Hypalon with vinyl coatings, representative of the industry's best, are shown in Table 7. While laboratory abrasion tests are not always valid, results of field experience have paralleled these tests. The good abrasion resistance obtained with Hypalon coatings is thought to be due, in part, to the low coefficient of friction of the polymer. This same property also results in a low level of dirt pick-up experienced when Hypalon-coated fabrics are exposed in highly industrialized areas.

TABLE 7

TABOR ABRASION TESTS OF VINYL AND HYPALON COATED FABRICS

500 gram weight, 100 revolutions, CS 10 wheel

	<u>Vinyl</u>	<u>Hypalon</u>
Weight loss/Revolution, gm	12.8×10^{-5}	8.1×10^{-5}

3. Good low-temperature flexibility. With special compounding techniques Hypalon appears to be adequate to fulfill the most rigid requirements. Fig. 7 illustrates the resistance to stiffening and embrittlement of typical Hypalon coating formulations exposed at subnormal temperatures.

4. Excellent resistance to mildew and fungus growth. As with polyvinyl chloride and neoprene, this is probably due to the presence of chlorine in the molecule. However, care must be taken in choosing the correct compounding agents, particularly plasticizers, since certain of these materials are known to be especially susceptible to fungus growth.

5. Good flame resistance. While Hypalon coatings will burn in the presence of an outside flame source, they will not support combustion when the flame is removed.

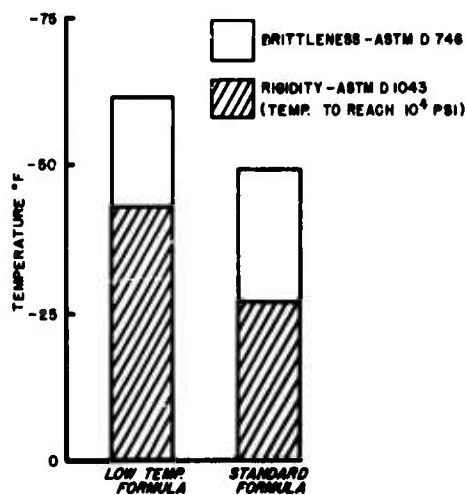


Fig. 7. Low temperature properties of "Hypalon".

TABLE 8

WATER VAPOR TRANSMISSION OF HYPALON

mg/in.²/24 hours at 75°F, 1 mil film

Hypalon containing magnesium oxide	26
Hypalon containing lead oxide	5

Fig. 8 illustrates the "life" of Hypalon coatings at various elevated temperatures in terms of the time for the elongation to reach

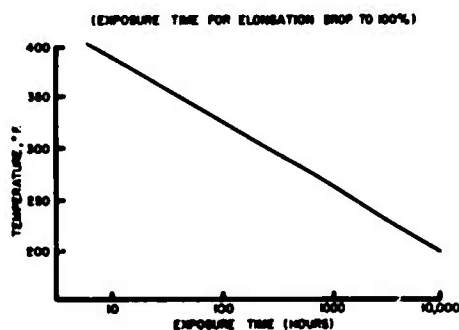


Fig. 8. Heat aging characteristics of Hypalon.

6. Permeability to most common gases intermediate between butyl rubber and neoprene. By changing the base Hypalon compound to water vapor transmission rate can be varied over a wide range as shown in Table 8.

7. Inherent resistance to oxidation. Hypalon can be utilized in elevated temperature services or when exposed to many fluids.

100% -- under which it is assumed that failure due to embrittlement may occur. Table 9 illustrates the effect of several typical fluids on Hypalon coatings.

Fabrication difficulties due to Hypalon's inert nature have limited its acceptance in certain fields unless the

TABLE 9
CHEMICAL RESISTANCE OF HYPALON

<u>Fluid</u>	<u>Conditions</u>	<u>Volume Change, %</u>	<u>Surface Appearance</u>
Water	100 days/158°F	12	No change
Sulfuric Acid, 66° Baume	100 days/RT*	13	Darkening and V. Sl. Pitted
20% Nitric Acid	100 days/RT	7	No change
20% Nitric Acid	100 days/122°F	30	Sl. Soft
Sodium Hypochlorite (20%)	100 days/RT	0	No change
ASTM #3 Oil	3 days/212°F	75	No change

* RT = Room temperature.

coated fabrics could be stitched or otherwise sewn. However, adhesives have been developed recently which are more than adequate for even critical seaming applications. For instance, Table 10 shows the bond strength developed and retained at test temperatures of 160°F in accordance with industry radome requirements. From the characteristics described it is evident that Hypalon coatings will be useful in many military coated fabrics applications.

TABLE 10
TYPICAL SEAM STRENGTH OF HYPALON COATED FABRICS

Dead weight on 2" x 1.5" overlap

<u>Temperature, °F</u>	<u>Weight held after 4 hours, lb</u>	<u>Peel strength p.p.l.i.</u>
75	600	25
140	300	-
160	260	-

"Urethane Polymers". Among the other new polymers that are gaining in commercial importance are the urethanes such as Vulcollan, Adiprene, Estane, Genthane, and Vibrathane. They are vulcanizable elastomers which are made by reacting polyols with diisocyanates. Characteristically, they have much greater strength and toughness than other elastomers or flexible plastics. Table 11

compares the strength and abrasion resistance of urethane rubber vulcanizates with those made from natural rubber. Their abrasion resistance can be further illustrated by the fact that several million miles of road tests comparing tire treads of urethane rubbers with the best commercially available today showed greater than a 2 to 1 wearing advantage for the urethane rubber.

TABLE 11

NATURAL VERSUS URETHANE RUBBERS

	<u>Natural Rubber</u>	<u>Urethane Rubber</u>
Hardness, Shore A	60	64
Tensile strength, psi	4400	5150
Stress at 300% strain, psi	1600	2475
Elongation, %	550	540
Graves' Tear, psi	350	380 (600)
Abrasion resistance, Bureau of Standards Index	100	232
DuPont Flexer, hours to first cracking	136	OK at 182

The urethane rubbers discolor in sunlight. Little long-term weathering information is as yet available to predict the life of coated fabrics exposed outdoors. However, a limited amount of data such as shown in Table 12 indicate the serviceable life may be in the same range as that of neoprene coatings.

TABLE 12

OZONE RESISTANCE OF URETHANE RUBBERS

Tapered Die -- 20% Elongation

<u>O₃ Concentration</u>	<u>Observations</u>
1 PPM	170 hours to trace cracking -- no further change in 270 hours.
100 PPM	4 hours to trace cracking -- 190 hours to noticeable cracks.

The brittle point of some of the urethanes is exceptionally low. A typical comparison with natural rubber is shown in Table 13.

While the urethanes generally tend to stiffen at a somewhat higher temperature than natural rubber, it is expected that thin coatings on fabrics would be outstanding under Arctic conditions.

TABLE 13
LOW TEMPERATURE PROPERTIES OF URETHANE RUBBERS

	<u>Natural Rubber</u>	<u>Urethane Rubber</u>	<u>Urethane Rubber plus Low Temperature Plasticizer</u>
Brittle point, °F ASTM D 746	-80	OK @ -80	OK @ -80
Temperature, °F, required to reach 10,000 psi in torsion ASTM D 797	-64	-35	-55

Urethane rubbers are available in both solid and liquid forms. While the solid polymers can be processed on fabrics in the normal manner, the liquids offer fascinating new possibilities in solvent-free fabricating techniques which could be particularly advantageous in the manufacture of complex articles.

"Specialty Heat- and Fluid-Resistant Polymers". Within the past several years a host of products have appeared which are far more resistant to degradation than conventional polymers when exposed to extremely high temperatures, fuels, and many chemicals. A number of these materials are shown in Table 14 with a brief resume of their outstanding characteristics.

Viton, a copolymer of vinylidene fluoride and hexafluoropropylene, is used as representative of this class of polymers for a more thorough discussion. Viton-coated fabrics can be manufactured in the same manner as those of other elastomers with two exceptions. First, Viton coatings must be post-cured or given a second vulcanization cycle to develop maximum properties. Second, since Viton is extremely inert to most solvents, without special techniques, it may be more difficult to adhere during seaming than conventional elastomers. Of course, stitched seams would be adequate under

TABLE 14
TYPICAL HEAT- AND FLUID-RESISTANT POLYMERS

Trade Name	Chemical Nature	Base of Fabrication	Tensile Strength (Typical Max.)	Heat Resistance Max. Service Temp. (°F)	Fuel Resistance	Chemical Resistance	Low Temperature Properties
Silicones	--	Fair	1500	600	Poor	Fair	Outstanding
Hycar PA	Acrylic acid ester copolymer with halogen-containing derivative	Fair	1800	350	Good	Poor	Poor
TEFLON	Polytetrafluoroethylene	Diff.	4100	600	Exc.	Exc.	Stiffens
VTTON	Vinylidene fluoride - hexafluoropropylene copolymer	Good	2500	600	Very Good	Very Good	Fair
LS 53	Fluorosilicone	Fair	1000	450	Good	Fair	Very Good
Kel F(3700 (5500	Trifluorochloroethylene-vinylidene fluoride copolymer	Diff.	2700	450	Good	Very Good	Fair
Kel F(1F4 (2F4	1,1 Dihydro-perfluorobutyl acrylate polymer	Good	1200	450	Very Good	Good	Fair

most service conditions. As will be readily understood after a consideration of Viton's properties, there are relatively few types of fabric that could be used in Viton constructions to withstand the same extremes of temperature or fluid exposure. To date, most coating work has been done on glass, stainless steel, asbestos, or teflon fabrics. For a few applications involving protective garments Dacron fabrics have proven to be quite satisfactory.

Depending upon thickness, Viton coatings may be slightly stiffer than those from conventional materials because of its relative high modulus. While few abrasion or wear tests under service conditions have been made as yet, a consideration of Viton's low coefficient of friction and innate strength would lead one to conclude that it would compare favorably with rubber or PVC. While light-colored coatings of Viton can be prepared, they tend to discolor. Further, the best qualities by and large are obtained in black systems, so they are generally preferred. Viton coatings have excellent resistance to ozone attack -- approaching that of Hypalon. When tested in ozone at 100 ppm for 400 hours under 25% strain, typical Viton vulcanizates showed no signs of cracking. Neither was any degradation evident after twelve month's exposure to direct sunlight. Viton coatings are nonflammable and do not support mildew or fungus growth.

Viton's potential in coated fabrics probably lies in three areas -- fuel cells (which may or may not be strictly classified as "coated fabrics"), diaphragms, and protective clothing. In addition to the properties outlined above, heat and/or fluid resistance are important factors in these markets. A summary of Viton's heat resistance is shown in Table 15. This is quite remarkable when considering that conventional materials such as neoprene, butyl or Hypalon would be degraded after a relatively few hours at 300°F. Many of the silicone and other fluoro-rubbers exhibit similar good resistance

to heat. Fabrics coated with Viton have remarkable stability under high temperature conditions. They fail normally due to polymer degradation and resultant chemical attack on the fabric as shown in Table 16. Viton was coated on glass fabric to a thickness of 10 mil each side and fabricated into a double ply construction. The vulcanized composition was then aged in an air oven.

TABLE 15

HEAT RESISTANCE OF VITON

<u>Temperature, °F</u>	<u>Estimated time to brittleness, hours</u>
400	2400
450	1000
500	250
550	72
600	24

TABLE 16

HEAT RESISTANCE OF VITON COATED GLASS FABRIC

<u>Conditions</u>	<u>Appearance</u>	<u>Weight Loss, %</u>
25 hrs/500°F	OK	2.2
50 hrs/500°F	OK	3.5
25 hrs/550°F	OK	5.3
50 hrs/550°F	Brittle	50.0

TABLE 17

FLUID RESISTANCE OF VITON

<u>Fluid</u>	<u>Test Temperature, °F</u>	<u>Volume Increase, %</u>	<u>Hardness Change, pts.</u>
Steam	400	4.8	0
Aircraft Fuel (JP 4)	75	0.8	+1
Hydraulic Fluid (OS 45)	400	11.1	-3
Phosphate Ester Hydraulic Fluid	300	270.0	-32
Carbon Tetrachloride	75	1.3	+2
Concentrated HF (48%)	75	4.8	+2
Fuming Sulfuric Acid	75	4.8	-4
Red Fuming Nitric Acid	75	74.0	-29

Table 17 illustrates Viton's resistance to a number of fluids. Standard test specimens were immersed for seven days at the temperature indicated. Resistance to permeation by most gases is very good, indicating Viton's use in the products mentioned above.

TABLE 18
LOW TEMPERATURE PROPERTIES OF VITON

	<u>Brittle Point, °F</u> <u>ASTM D 746</u>
0.075" thick specimen	-42
0.025" thick specimen	-55
0.010" thick specimen	-70*
<u>°F</u>	<u>Clash-Berg Stiffness, psi</u>
75	240
16	640
8	1231
0	4100
-5	12000

* Estimated from similar test.

As seen in Table 18 the vulcanizates stiffen at moderately low temperatures. Since these tests were made with relatively thick sections, it is probable that thin coatings would perform satisfactorily at lower temperatures. Certain silicone rubbers on the other hand have outstanding resistance to stiffening and embrittlement at low temperatures; in fact, several times better than natural rubber. Their use is certainly indicated under extremely critical low temperature conditions. Typical low-temperature properties of three silicone grades are shown in Fig. 9.

Future Construction Methods. The coated fabrics industry is facing new competition today in the field of unsupported plastic films. They are being used for a wide range of applications, such as tarpaulins (or other protective coverings), irrigation piping, and pneumatic buildings. While competitive experience would indicate that such materials may complement rather than replace coated fabrics and thus broaden the horizons of engineers and designers for new units

of construction. Some of these plastic films may very well utilize textile reinforcement but perhaps to a degree and in a fashion quite different from the norm today.

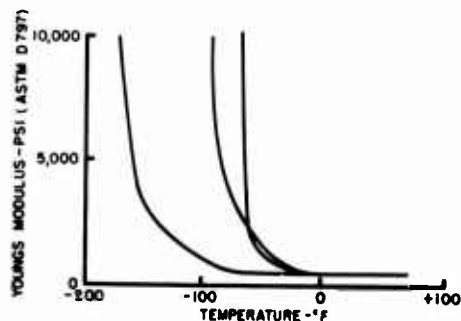


Fig. 9. Low temperature properties of silicone rubbers.

Three chemical classes typify the thermoplastics (other than PVC) which today show considerable future promise:

Polyethylene films can be produced in thickness of less than one mil, are extremely lightweight and flexible, and have very low

water vapor transmission rates. As seen in Table 19 polyethylene films are relatively tough and have good elongation; however, tearing of thin films could be a problem. The weather resistance of clear polyethylene is poor, but recent technical advances in pigmentation have produced black films with excellent weatherability. Polyethylene burns slowly (like wax). Thus, these plastics may find military application as expendable covering materials where the technical requirements are not severe and economy is paramount.

Transparent nylon films have much greater tensile, abrasion, and tear strength than polyethylene, fair resistance to weathering, and quite low gas permeability. They are stable for short periods of time at temperatures as high as 450°F and retain flexibility at temperatures as low as -100°F. Nylon films are self-extinguishing to flame and have good resistance to many chemicals and hydrocarbon oils. While they have limited outdoor utility, it is expected that they will be widely used in packaging foodstuffs, medical supplies, and oils or greases for military consumption. The use of nylon films as inert barrier coatings in large coated fabric containers for bulk fluid shipments has already been considered.

TABLE 19

CHARACTERISTICS OF POLYETHYLENE FILMS

Tensile strength, psi	1900
Elongation, %	600
Brittle Point, ASTM D 746, °F	-100
Softening Point, °F	175-200

Gas Permeability

10^{-8} cc/cm²/cm thick/sec/atm,
25°C - 0% RH

Hydrogen	4.1
Nitrogen	0.42
Oxygen	1.3
Carbon Dioxide	5.1

Water Vapor Transmission

mg/in.²/24 hrs @ 75°F
(1 mil film)

0.5

Transparent polyethylene terephthalate (Mylar) films are outstandingly strong and puncture resistant, quite chemically 'nert, and impermeable to gases. Films as thin as 1/4 mil are tough, but flexible. Basically, Mylar has fair weathering resistance, although recent technical developments indicate that special compositions can be utilized satisfactorily outdoors. Several pneumatic storage buildings have been fabricated from this material. The seams were made using adhesive bonds in a conventional manner. The completed structures are transparent, easily transported, and quite impermeable to supporting air loss. Summary. As the requirements of the military coated fabrics industry grow increasingly complex, new polymer development has provided raw materials to satisfy most of the demands. Today a host of coating materials are available to assist the designer in the utilization of coated fabrics on an ever-broadening base. However, he must recognize the limitations of each material and accurately specify to the manufacturer the balance of properties desired to insure maximum service life.

References

1. Aiken, W. H., P. M. Doty, and H. Mark, Water Vapor Permeability, Modern Packaging, 137-166 (August, 1945).
2. American Society for Testing Materials, ASTM Standards on Rubber Products, (May, 1958).
3. Ashcroft, J. M., Evaluation of Rot Resistant Treatments for Elastomer Coated Fabrics, Corps of Engineers, U. S. Army, U. S. Department of Commerce PB 121420 (July, 1955).
4. Briganti, R., Shelf Life of Neoprene Coated Nylon Fabrics, Department of the Navy, U. S. Department of Commerce PB 111728 (April, 1955).
5. Catton, N. L., The Neoprenes, 1953, E. I. duPont deNemours & Co., Inc., Wilmington, Delaware.
6. Silicone Rubber, 1957, Dow-Corning Corporation, Midland, Michigan.
7. E. I. duPont deNemours & Co., Elastomer Chemicals Department, Internal Reports.
8. Ibid, Report BL-41, Fungus Growth on Elastomers (May, 1942).
9. Ibid, Report BL-66, Mildew and Fungus Resistance of Rubber and Neoprene Coated Fabrics (January, 1943).
10. Ibid, Report BL-247, Low Brittle Point Neoprene Compounds that are Fungus Resistant (July, 1952).
11. Ibid, Report 58-3, Viton A and A-HV (May, 1958).
12. Ibid, Report DPR 4, Adiprene C - A Urethane Rubber (July, 1957).
13. Ibid, Report 57-10, Effect of Chemical Media on Hypalon (October, 1957).
14. Ibid, Report 56-4, Hypalon 20 (September, 1956).
15. Ibid, Report BL-327, Weathering of Neoprene-Coated Nylon Fabric (August, 1957).
16. Ibid, Report 56-10, Coatings of Hypalon 20 Synthetic Rubber (November, 1956).
17. E. I. duPont deNemours & Co., Polychemicals Department, Internal Reports and Sales Brochures.
18. Modern Plastics Encyclopedia, 1957, 35, Breskin Publications, Inc., Bristol, Connecticut.

19. Setter, Lt. D. E., Development of Hypalon-Coated Dacron and Its Use in Lightweight Air-Supported Radomes, Rome Air Development Center, ASTIA Document AD-97760 (November, 1956).
20. Stout, L. E., R. Geisman, and J. M. Mozley, Jr., Diffusivity of Gases Through Synthetic Elastomer Diaphragms, Chemical Engineering Progress, 44, 219-228 (March, 1948).
21. Thompson, D. C., J. F. Hagman, and N. N. Mueller, Flame Resistance of Neoprene -- Effect of Compounding Ingredients, E. I. duPont deNemours & Co., Inc. -- Contribution No. 120 (September, 1957).
22. Whitby, G. S., Synthetic Rubbers, 1954, John Wiley & Sons, Inc., New York.

Chairman Thomas: In introducing the next speaker, I think I can make the following statement: If you don't already know him, then I am one hundred percent confident that you are not in the coating fabric business. We are very fortunate to have with us today the Technical Director of the Hodgman Rubber Company. Mr. Joseph Haas will speak to us on the Technical Problems of the Coater.

TECHNICAL PROBLEMS OF THE COATER

JOSEPH L. HAAS -- Graduated cum laude from Harvard in 1923 with a B. S. in Industrial Chemistry. Subsequently he took courses at both Massachusetts Institute of Technology and Columbia, as well as night courses in Textile Chemistry at MIT and courses in Rubber Technology. Mr. Haas was employed by Western Electric Company in Chicago and Westinghouse Company in Bloomfield, New Jersey. He has been employed by Hodgman Rubber Company for the last thirty years and at present is the Technical Director. He has served as Chairman of the Boston Rubber Group, as Vice-Chairman of the Boston-Providence division of S. P. I. and is a member of the latter as well as the American Chemical Society and A. S. T. M. He has served on various committees, principally committees dealing with coated fabrics and items made therefrom.

In asking me to speak to you on the technical problems of the coater, Professor Backer suggested that I touch on the following:

1. A brief survey of commercial coating techniques to meet end use requirements.
2. Formulation of coatings.
3. Fabric selection to meet end use requirements.
4. Case studies of the whole problem including formulation, fabric design, and coating techniques.

This is a large order and I shall attempt to condense these items as much as possible. I will not trouble you with slides or charts and will be as non-technical as possible.

Proofing, a term undoubtedly derived from "water"- or "weather"-proofing, was originally restricted to the coating of fabrics with rubber. Later it also embraced coatings made from oxidizable oils and pyroxylin. Today, the term covers all flexible coatings including those made from the newer synthetic rubbers, elastomers, and vinyl resins regardless of end use.

There are many methods for coating fabrics; e.g., dipping, saturating, spraying, various methods of roller-coating, and lamination of precalendered, cast, or extruded films onto fabrics. Nevertheless, it is safe to say that the bulk of coated fabrics are still made by one of two general methods; namely, knife and calender coating. The coating materials we need to consider are essentially the various rubbers and the vinyl resins. This consideration does not exclude nor, in any way, attempt to detract from the importance of other methods of coating or from other coating materials.

Knife coaters can be classified into two types: the knife-over-roll or rubber spreader, and the floating knife or pyroxylin coating machine.

The ordinary rubber spreader consists of a rubber-covered roll, directly over which is stationed a relatively thin knife blade

vertical to the surface of the roll. This knife can be raised or lowered by means of a screw arrangement to alter the spacing between the knife edge and the roll. Fabric from a tensioned let-off roll passes between the knife and roll, over a heated table or thru a drying chamber, and is wound up again on a wind-up shell. Stock of a relatively viscous nature is fed onto the fabric at the point where the fabric passes under the knife edge. The travel of the fabric under the knife causes the stock to be scraped or "spread" onto the fabric -- the setting of the knife determining the amount deposited. Successive passes are made until the required amount of coating has been built up. The stock, generally a solvent solution of rubber or vinyl resin (a latex or dispersion may be used), is dried as it passes over the steam table or through the heated chamber. In some cases, actual vulcanization or fusing may occur. Variations and modifications of this simple set-up exist. This method is used largely for lightweight coatings or coatings of extremely low rubber content. On the other hand the calender method permits the deposition of heavy coatings in a single pass.

In the case of the pyroxylin coater or floating knife machine, the knife is stationed between two supporting bars or rolls. The knife may be thin-bladed as in the case of the rubber spreader or it may be one with a rounded edge, as much as one-half inch in diameter. Not only can the knife be moved up and down vertically against the fabric, but it can also be stationed at a forward or backward angle to the fabric. Thus, the amount of stock that is metered onto or into the fabric can be adjusted by the shape of the knife-edge employed and its angle to the fabric as well as by the pressure of the knife against it. This type of machine is largely employed in the coating of vinyl resin dispersions; the organosols and plastisols.

Calenders, unlike knife machines, do not use fluid stocks. Rubber or vinyl masses, which are brought to a plastic condition by heat and mechanical mixing, are used. Calenders are massive machines employing 3 to 5 large, heavy, steam-heated rolls or cylinders, 12" or more in diameter and from 40 to 120" long. These rolls may be positioned vertically one over the other or in a straight or inverted "L" or "Z" position. The plastic mass of rubber or vinyl is fed from two roll mills into the nip between the upper two rolls of the calender. A continuous sheet of plastic of relatively uniform thickness is formed and travels around the face of the next lower roll. For ordinary coating work, the face and lower roll travel at the same speed. The fabric, generally base- or anchor-coated by the spreader method, passes between these last two rolls. By adjusting the desired pressure, the plastic sheet from the face roll is attached to the fabric. This composite is carried off to receive further surface treatment and cooling.

Essentially, all of these machines have changed little in principle over the years, but many refinements and attachments have been made to cope with the newer rubbers, resins, and fabrics and to produce better coatings at greater speeds with less manpower.

Now let us look at coating materials and base fabrics.

Thirty-five years ago, our compounds consisted mainly of natural rubber of varying quality, reclaims, tars, pitches, and factices; naturally occurring fillers such as ground limestone, barytes, and clay; inorganic colors such as iron oxides, iron blues, chrome greens, zinc oxide, and lithopone; organic colors that were poor in quality and expensive; litharge, lime, and antimony sulfides as vulcanizing agents; a few new organic accelerators, difficult or dangerous to use; and, of course, sulfur. The only fabrics we had to concern ourselves with were cotton and silk, with occasionally some wool or linen. Although cellulose acetate and rayon were

appearing, they had not as yet become sufficiently available to give us the headaches that they did at a later date. Most garments were drab in color. With the exception of work garments and police and firemen's raincoats which were calendered coatings, litharge-cured, and made from compounds that were generously loaded with reclaim and pitches, most of the coatings were made by the spreading method, consisted of rubber and white factice (sulfur chloride treated corn or rape-seed oil) and the various other compounding materials, and were sulfur chloride cured either by the vapour or solution method. These methods of curing never lent themselves to good technical control and the quality of the coatings varied considerably.

Many of the proofing plants had no laboratory equipment whatsoever, whereas the average equipment consisted of a laboratory mill, calender, vulcanizer, some churns, possibly a hydrostatic tester, and a Scott tester for testing the strength of fabrics. The latter two were essentially the only pieces of testing equipment used, with the possible exception of an oven for dry heat aging tests. In most plants, the standard method of testing a fabric for hydrostatic value was to spit on the coated side of the fabric and to use the pressure of the thumb to see how readily it could be forced through to the fabric side. The standard abrasion test was made by folding the fabric, coated side out, and rubbing it sharply against one's trouser leg. Although no one has ever been able to specify the exact nature of the material that should be used in the trouser, nor the speed and pressure with which the rubbing is to be performed, there are still many coating experts who consider this test of far more value than those now made on standard testing machines to measure abrasion resistance.

Today the situation is startlingly different. Not only have we literally hundreds of new organic rubber accelerators (specific in

their action, permitting more rapid vulcanization, and producing better quality products), antioxidants, antiozonides, better reinforcing agents, pigments, organic colors, processing aids, and chemicals of all sorts to meet specific requirements; we also have a host of new synthetic rubbers, ever increasing in number, all of which differ radically in their manner of compounding and processing, but permitting the user to formulate coatings never attainable with natural rubber. In addition to these, we have the vinyl resins which require an entirely different manner of compounding and formulating, and the organosols and plastisols which require entirely new techniques for preparation and processing. Who ever heard of dilatancy, thixotropy, yield, fusing temperatures, and the other rheological properties of coating materials twenty years ago? Today one must be acquainted with heat and light stabilizers as well as a variety of plasticizers having some of the following properties; retention of flexibility at extremely low temperatures and permanence at relatively high temperatures, no discoloration in sunlight, immune to attack by fungus, non-toxic, odorless, non-spewing, flame resistant, and possessing other characteristics to meet specific conditions demanded in the finished coating. As a result and in addition to the rubbers, an array of compounding materials are available for coating. Because of the overlap between the rubbers and the newer resins and elastomers for similar applications, it is necessary that the rubber compounder (in all fields of endeavor) keep abreast of the new developments and apply them to his problems.

Paralleling the progress made with the newer elastomers and compounding ingredients, has been the work done in synthetic fibers. The late thirties and early forties heralded the introduction of nylon. Today, we have to deal not only with the fabrics made from natural fibers, the cellulose derivatives, and nylon, but also

with Dacron, Orlon, Chemstrand, to mention a few of the organic synthetic fabrics, as well as unwoven fabrics made from various fibers, and glass cloth. Each presents problems of dimensional stability, of the ability to accept colors satisfactorily in dyeing, of obtaining satisfactory adhesion with coatings, of slip and stretch, and of static pick-up.

The advent of war in Europe in 1939 and our own subsequent participation in 1941 forced us, much faster than would ordinarily be the case, into the use of these new rubbers, vinyls, and synthetic fabrics. As we approached the point where natural rubber would no longer be available, we had to turn first to neoprene, shortly thereafter to the vinyl resins, and finally, to Buna S and acrylonitriles. Cotton fabrics also became scarce, and the government decided that nylon, light in weight and strong but as yet a fairly unproven fabric, should be used, particularly in protective garments for the services.

The weavers and finishers of this new fabric, attempting to adapt cotton machinery and practices to this new fiber, had their problems, but they were simple compared to those that confronted the coater. Proper heat-setting and stabilization of the yarn and fabric was unknown. As a result we were faced with a fabric which had many faults; for example: loose selvages, baggy areas, unheard of stretch, shrinkage under heat, tremendous static build-up, corrugation under vulcanization, and many other defects. In addition the adhesive characteristics of this fabric appeared to be very poor. And to cap it all, we had to work with coating materials, relatively new or entirely foreign to us.

During the intervening years, Industry and the Services had sought for and demanded products of better and more uniform quality, had devised new testing equipment, and had given great impetus to organizations, such as ASTM, to draw up standard testing procedures. In addition to taking part in this work, the proofing

industry had set up its own technical committees under RMA, and later under SPI and the Vinyl Coaters Association, to carry on similar work. The demands of warfare and the many new qualities sought in coated fabrics not only spurred this work, but also brought about many additional methods, and consequently, new testing equipment. It is probably unnecessary to say that as these newer coated fabrics were put into actual use by our Armed Services, that hithertofore unsuspected failures occurred, requiring a constant change and improvement in specifications, often resulting again in newer test methods and equipment. A comparison of an Army raincoat fabric specification of the early thirties and one of today, or better still, the present specification for impermeable cloth for gas and toxicological agents will quickly reveal the progress made in attempting to define exactly what is required in a satisfactory coated fabric.

As an example of unsuspected shortcomings or failures that had to be corrected quickly during the war, we might cite the vinyl coated raincoat and poncho fabric. It is an inherent characteristic of the vinyls to grow increasingly stiff as the temperature drops and as a result, vinyl garments become noisy under motion. We are told that at the Battle of the Bulge the location of our troops in the darkness was revealed to the enemy by the rustle of their garments. They were wearing raincoats and ponchos over their overcoats for added protection against the bitter cold. In the tropics, many garments stuck together badly and, in some cases, the coating actually was removed when they were being unpacked. Bacteria and fungus attacked certain of the plasticizers so badly that the coatings became stiff and the garments unusable. All of these failures were attributable to an excusable ignorance of the role of plasticizers and vinyl resins in coating formulations. Newer plasticizers had to be devised to overcome these faults or existing

plasticizers and vinyl resins chosen more judiciously, the specifications altered to avoid similar occurrences, and proper test methods set up accordingly.

As another example, the introduction of nylon as coating fabric brought about many problems, one of which was the difficulty that existed in obtaining good adhesion between the smooth filament yarns and the ordinary coating materials. Neoprene, however, gave much better adhesion than any of the other elastomers. The Navy sought to obtain a certain neoprene-nylon garment to be used under water. Adhesion values, apparently entirely adequate as measured by the usual methods, were written into the specifications, and the garments let out for bid. Our own limited work with neoprene and nylon to this point had made us aware that the ordinary adhesion tests could be very misleading. Although one might obtain very satisfactory adhesion on a neoprene-nylon fabric as tested by the conventional methods, we had found that if such a fabric was subjected to a small amount of flexing and scrubbing, as would be encountered in wear, particularly if this was done on a garment that was wet, the actual adhesion values would drop sharply and result in almost immediate failure. Material that had already been submitted to and approved by the Navy was consequently flex tested and as we had anticipated, failure resulted. Thus, the specification was immediately revised to include a scrub and flex test and the use of a chemical bonding agent recently introduced to industry to insure good adhesion.

Hundreds of similar examples could be cited. In most cases, in their own laboratory or because of reports of failures coming back to them from the field, the Services themselves first became aware of the shortcomings of a certain item or specification. In many cases, it was the coating technician who advised them that they were overlooking certain details that had need for correction

or inclusion into the specification. The advantages that are accruing to both the Services and Industry by this close liaison between their technical staffs are tremendous. Industry has profited greatly in its civilian work from the problems that had to be corrected or solved in its relations with government agencies.

Exactly how does the technical coater tackle a problem?

I will take a case where we worked closely with the Quartermaster Research and Engineering Command in working out one particular problem.

The present vinyl-nylon poncho material has certain inherent faults that make it desirable to replace it with a better all-around protective coated fabric. Such a material should offer protection not only against weather, but also against poisonous and vesicant gases and liquids, at least to a limited extent; be able to serve as a ground cloth and shelter material; withstand cold conditions without stiffening; and, in particular, offer better protection against the high temperatures of sudden flash flames and napalm attack. Plasticizers in the vinyl resin coatings permit easy passage of certain poisonous and vesicant gases and liquids. Even though improved by low temperature plasticizers, the coated fabric becomes undesirably stiff at low temperatures. Under napalm attack, the coating and the nylon fuse into a burning mass almost instantaneously, attaching itself to the clothing or skin of the wearer before he can rid himself of it. A coated cotton garment does not melt; therefore, the wearer has a few moments in which to dispose of it before damage results to the surfaces under it. However, lightweight cotton garments, in general, have too many drawbacks for modern warfare requirements.

What then was the nature of the coated fabric that was required?

The following were desirable:

1. Be light in weight.

2. Possess high breaking strength.
3. Possess high tearing strength.
4. Be pliable and retain its flexibility at low temperatures.
5. Have good dimensional stability.
6. Have good flex and fold resistance.
7. Be reasonably flameproof and flame-resistant, and not become thermoplastic under heat.
8. Be reasonably impermeable to gases and liquids.
9. Have good hydrostatic resistance.
10. Possess reasonable resistance to oils and the ordinary chemicals that might be encountered in service.
11. Retain its physical properties under reasonably high temperatures: no exudation, adhesion to self, or decomposition.
12. Possess good adhesion of coating to the fabric base.
13. Possess good abrasion resistance.
14. Possess good resistance to weathering, sunlight, and ozone.
15. Retain its color, and chalk slightly, if at all.
16. Be resistant to mildew and bacteria attack.
17. Possess no dermatitis producing qualities.
18. Possess the proper infra-red reflectance qualities.
19. Have good aging qualities in service and in storage.

One will note, at once, that many of the desired properties must be derived from the fabric base. Lightweight and high strength can only be obtained from the synthetic fabrics. Cotton has good heat stability and can be made flameproof; however, cotton is exceptionally weak in lightweight constructions. Like all fabrics made from short length fibers and whose fiber-ends detract from a smooth surface, cotton requires relatively heavy coatings to make it gas- and liquid-proof.

Nylon is our first thought but, along with the other organic synthetic fiber fabrics, its heat stability is poor. Some of the other organic fabrics can be made to have better dimensional stability and possess other desirable properties, such as superior resistance to sunlight deterioration, but must be rejected because of failure under heat. Our next thought is glass-fiber cloth. It has high strength with relatively low weight, good dimensional stability, and good flame resistance. It has, however, several shortcomings. Most seriously, it fails quite rapidly under folding and flexing. The yarns break and lose their strength. Good adhesion is hard to obtain with most coatings and is destroyed quite quickly under flexing and bias-stretching. The coated fabric lacks the proper flexibility and is hard to assemble into a garment. Other faults also exist.

Cellulose Acetate has many of the weaknesses of the organic synthetic fibers. It is readily attacked by many ordinary solvents and chemicals and, like rayon, loses much of its strength when wet. Rayon has fair strength and can be made relatively flameproof but loses too much of its strength when wet. Thus we come to Fortisan. It loses some strength when wet, but considering its initial strength, it is not too bad. It has good dimensional stability, is easy to flameproof, is mildew-resistant, is relatively little affected by high temperatures, and has adequate flexibility and resistance to folding and flexing. It is, however, a relatively non-extensible fiber and, when coated, loses much of its tear resistance. Thus, if we take the lightweight low-denier, high count Fortisan fabrics, even those made in a rip-stop construction, we find that when these are coated, unlike similar constructions of nylon or Dacron, most of their tear resistance has been lost. Its other properties, however, are such that it was worthy of further consideration.

We were aware of the fact that nylon fabrics reasonably light in weight, made from higher denier untwisted yarns in much lower count constructions, gave far higher breaking and tear strengths than the conventional lightweight nylons of similar weight. How about applying these principles to the construction of a Fortisan fabric? Possibly in such a construction, we could at least attain the tear strengths and breaking strengths that we had in the present lightweight nylon which had proven satisfactory for the purpose intended. We set about to investigate this possibility. Collecting as much data as possible on the properties of coated nylons and Fortisans, with particular reference to tear and strength, we came to the conclusion that if a fabric could be constructed somewhat similar to the 2 oz fiber-thin construction in nylon, we should have a fabric which, when coated, would have as good or slightly better tear resistance than the coated 1.6 and 1.8 oz nylon twill currently used in ponchos.

The first reaction from fabric experts and weavers was that we were all wrong. Our analysis had covered the low-denier, high count nylons and Fortisans and the high-denier, low count nylons. Unfortunately, no high-denier, low count Fortisans were obtainable and we had projected our findings from the data we had into the area of a theoretical Fortisan fabric. That, we were told, could not be done. Yet, we felt that we were right and wanted to be shown. But, we were told that no Fortisan of the denier we propose to use was available. Our answer was: Twist or ply together Fortisan of available denier to approximate what we want. But, we were told that such constructions would be too sleazy, would be impractical to weave, and unmanageable in coating. However, we were able to find one weaver who was partially convinced that we were right and that such a fabric could be woven. He succeeded in weaving not one but several constructions along the lines of what we wanted,

TABLE 1

HODGMAN RUBBER COMPANY
Framingham, Massachusetts

Laboratory Report

Uncoated	Style	1.8 oz Nylon Tw.	Fortisan Fabrics				
			7206	7207	7208	7209	9999
							HW 3137
Wt/Sq Yd		1.7	2.23	2.12	1.84	1.91	2.11
Yarn Denier		7.0	150	120	120	150	60
Count		84 x 84	56 x 56	66 x 66	57 x 58	47 x 48	68 x 68
Tongue Tear (1)		8 x 8	13 x 13	9 x 9	11 x 11	16 x 12	5 x 5
Brk. Strength (2)		106 x 104	129 x 141	116 x 115	100 x 100	105 x 100	116 x 109
Source			Stern & Stern	Stern & Stern	Stern & Stern	Stern & Stern	Celanese
							Celanese
<u>Coated</u>							
Designation		TD-7853	A-897A	A-897B	A-898A	A-898B	A-904
Wt/Sq Yd		7.6	8.46	8.05	8.5	7.77	8.23
Tongue Tear (1)		4 x 3.5	5.5 x 5	5 x 4	4.5 x 3	5.5 x 4	3.5 x 2.5
Elmendorf Tear (3)		30 x 29	55 x 39	43 x 30	36 x 32	57 x 33	37 x 25
Brk. Strength		125 x 120	132 x 130	132 x 94	108 x 90	124 x 100	152 x 140
Thickness		.0085	.0088	.0085	.0080	.0080	.0080
Flexibility		6.2	8.4	7.8	7.7	8.4	9.0

(1) Tongue tear values are the mean of high and lows; i.e., on a finding running with a low of 4 and a high of 20, the resulting value would be 12.

(2) Breaking strengths are by the "Grab" method.

(3) Elmendorf values are scale readings made with augmented weights.

and these were coated and tested. The results (Table 1) were gratifying and our predictions of the properties that we should obtain, confirmed.

Now to obtain the proper coating.

From the standpoint of gas impermeability, we knew that butyl was the best bet. One factor, however, ruled out butyl as well as natural rubber and most of the synthetic rubbers, that is, the inability to impart some degree of flameproof without sacrificing almost every other physical property. The silicones, for many reasons, need not be considered. We needed a halogen-bearing polymer. The vinyls were out for the reasons explained before. We naturally turned to neoprene. It alone, at that time, was available in other than pilot plant lots, was reasonable in price, and could be readily compounded to give flameproof properties. It could be compounded to give the necessary low temperature and flexible characteristics desired. Such coatings would have good hydrostatic properties and resistance to oils and the ordinary chemical agents that might be encountered. They would have reasonably good resistance to poisonous gases and liquids. They would have good weathering characteristics, resist degradation by sunlight and ozone, exhibit no exudation or sticking at high temperatures, possess good resistance to fungus growth, and present no undue dangers in producing dermatitis. They would age well in service or in storage. With the judicious use of the isocyanate chemical bonding agents, if needed, we would get good adhesion of the coating to the base fabric. Satisfactory abrasion resistance, equal or better to that existing on the present vinyl coated poncho, was obtained. An olive drab color, having the desired infra-red reflectance values, was worked out in conjunction with the Quartermaster Corps.

Some chalking on weathering, probably of minor significance, does occur and although the coated fabric to be manufactured along

these lines is now ready for initial procurement before final adoption by the Army, it is conceivable that a top dressing of Hypalon may be desirable to correct this fault, as well as to improve abrasion, ozone and gas resistance, and appearance. The fact that Hypalon does not have as good low-temperature properties as neoprene should not militate against its use as a thin coating replacing the inert dusting material which will, otherwise, be used to remove the drag or tack from the neoprene surface.

Naturally, in the development of this coated fabric, certain criteria had to be met. A great deal of testing on laboratory and small plant runs were made before the desired end-points were attained. Although a broad knowledge of and experience with the many available coating materials and fabrics are prime requisites in developing a new coated fabric or in meeting an existing specification, experimental runs and concomitant testing are necessary to arrive at a successful solution.

But our problem does not end with the production of a successful sample run. How well can it be produced on a production basis? Too often, problems arise at this point that had not been apparent before. Due to the relative inelasticity of the fiber in this particular product, some of the questions to be answered are: Is the weaver going to have problems in preparing uniform fabric which will be free of tight and loose areas and which will run flat and true in coating machines? Are we going to be faced with new problems of tensioning in production-sized rolls? Looking back on the problems that the fabric weaver, the finisher, and the coater have encountered in the new synthetic fabrics in the past, I have no fears. Problems will always be with us and it is our task to solve them.

In this one example, I have tried to present a case history of the type of problem that faces the coating technician and the manner in which it is tackled and finally solved.

Because of the amount of the subject matter to be covered and the time allotted, I realize that my treatment has been superficial and concise. Nevertheless, I hope I have given you a slight insight into the work and problems of the coater.

Chairman Thomas: One of the integral factors in the development of coated fabrics is the very important field which the next speaker will discuss. It is the Evaluation of End Item Performance. This subject will be covered by the Chief of the Physical Testing and Quality Control Laboratories of the U. S. Rubber Company, in Mishawaka, Indiana.

The speaker, Mr. K. L. Keene, has a very intense interest in this field. He is Chairman of the Committee for Testing of Coated Fabrics in the A. S. T. M. We are very fortunate to have Mr. Keene here to discuss this essential link in the development of the coated fabric.

EVALUATION OF END ITEM PERFORMANCE

K. L. KEENE -- Is manager of the Physical and Service Testing Laboratories of the Mishawaka Plant of the United States Rubber Company and has had 33 years experience in the testing of rubber and plastic products. He is active in the American Society for Testing Materials and is at present Chairman of Subcommittee XXIV of D-11.

The discussion on the evaluation of end point performance will be confined to the practical viewpoint of twenty-six years experience in the physical and service testing of coated fabrics. This discussion will cover the following points:

1. Purpose.
2. Information needed for writing a specification.
3. Testing a product -- service tests.
4. Testing a product -- review of some present test methods.

5. Testing a product -- new test methods.
6. Value of investigating actual service conditions.
7. Summary.

Purpose. The purpose of evaluating the end item performance of a product is to assure satisfactory service. This evaluation may be from the point of view of a manufacturer who is producing goods for the general public, or it may be from the standpoint of a buyer who is writing a specification for a certain usage or evaluating a product for correlation with a specification already established. In any case, tests must be conducted according to designated test methods and the product must meet definite standards.

Information Needed for Writing a Specification. It is our opinion that the various tests set up in a specification should be the result of a thorough study of the conditions under which the product will be used, and, if possible, study of the material after it has been subjected to actual service conditions.

We know that in actual production there is not sufficient time to service test each production run and that laboratory tests must be made. If laboratory results will predict service life, then they are valuable and of considerable consequence. On the other hand, if the specification has been written without taking into consideration the actual service conditions, then it is quite possible that there will be certain conditions in the specification which will add to the production cost of the product, without increasing its serviceability. Another possibility is that the product produced to meet this specification may meet the requirements, and yet not yield a satisfactory end product. Therefore, the producer or the purchaser must make a thorough study of the end use of the product and list properties which are necessary to assure good serviceability. All tests which have no bearing on the end use should be omitted but extreme care must be exercised to include all pertinent tests along with adequate standards.

Testing a Product -- Service Tests. The service testing of a coated fabric can be conducted by numerous methods. The main objective, of course, is for the evaluator to obtain material which has been subjected to the maximum amount of wear for which it was intended. Because of the many uses of coated fabric the service testing will depend upon its intended use. For instance, if a material will be used for tarpaulins it is easy to have a test tarpaulin made for the trailer of a semi-truck. Arrangements can be made with a trucking company for them to use this tarpaulin under the same conditions as if they had purchased it. The worn tarpaulin must be returned to the laboratory for inspection.

When an item is being service tested it is probable that the test will include some standard material and some experimental. In the case of a tarpaulin this can be arranged by alternating panels of material one standard and one experimental.

Seating material can be tested in taxis where it is possible to obtain a much faster test run than in an ordinary passenger car. Taxis have passengers in and out all day long and in the South Bend area they travel an average of 1500 to 2000 miles per week.

Other coated fabrics can be service tested in the same manner by determining the end use and then making the necessary arrangements. If the material is for some specialized use which makes the service testing impractical due to this specialized use, it may be possible to improvise a service test. An illustration of this is one we had in our plant where a new type of women's footwear was developed several years ago. This development reached the finalizing stage in the summertime after laboratory tests had indicated a very satisfactory product, yet there were no tests under actual winter wearing conditions. These tests were improvised by taking the footwear to Mount Rainier where college students were employed to wear the shoes in snow. This gave test results which duplicated actual winter wearing conditions.

The combination of laboratory test results along with either actual or improvised service test results will give the manufacturer sufficient information on which to base a decision regarding introduction of a new product.

Testing a Product -- Review of Some Present Test Methods. In order to show the problem which confronts the writer of a specification I am listing all of the various tests for coated fabrics that are listed in specifications or test methods which we have in our plant. These were obtained from ASTM and various Automotive and Federal Test Methods¹. In most of these requirements the base fabric plays a very important part. This list covers 250 different tests which are available to the writer of a specification for coated fabric. Only a few of these tests will be discussed.

I would like to select some of the tests and analyze the problems confronting the writer of the specification when he selects the most suitable type from those which are available.

When selecting the proper tear test to use, the writer has a selection of three tear tests. Two of these are conducted at specified or given rates of speed such as 2, 12, and 20" per minute jaw separation speed on a conventional tensile machine. The other one is made at a faster rate of speed such as that produced by a falling weight or pendulum. We believe that tear tests are very important because the manufacturer of a fabric can produce a fabric highly resistant to tear and have the processer ruin the tear resistance of the fabric in several ways; such as, 1. tenderizing it by too much roll pressure in the calender, 2. striking a stiff coating completely through the fabric so as to prevent fiber slippage, and 3. coating it with a material containing certain chemicals which will tenderize the fabric.

1. Listing appears in Appendix at the end of this paper.

If the tear test in service is one which occurs due to a rapid action, we would suggest the falling weight or pendulum type of test. However, if the tear is the result of a slow tearing action such as would occur in the splitting of a seating material we would suggest a tear test such as the trapezoid or tongue tear. In addition to the regular tear tests there is another type of tear test known as the Stitch Tear Test. This was developed by duPont and is being evaluated by Subcommittee XXIV of D-11 ASTM. To date, the correlation of test results between laboratories looks very promising and the test may possibly be recommended for adoption as a standard ASTM Test Method. The equipment consists of a jig containing five phonograph needles which simulate stitches when the test specimen is forced onto them. The test involves mounting the jig in the upper jaw of a tensile machine, forcing one end of the test specimen onto the needles and clamping the other end of the test specimen in the bottom jaw of the tensile machine. The jaws are then separated at 12" per minute. The resulting tearing action duplicates the effect of stitch tearing quite well. We believe that this test will be a good means of evaluating the ability of a material to resist tearing which might occur as a result of sewing.

Abrasion tests are very frequently specified in specifications but I wonder why. We have eight different abrasion tests listed in specifications available to us in our plant and we know of at least one more, yet we know of no test which will correlate with actual service. We also know from an ASTM round robin test conducted several years ago that the correlation of results between eleven laboratories using two well-known abrasion testers is non-existent. This round robin gave results so far apart that the results were ridiculous. These round robin results varied from 767 cycles to cause failure in one laboratory to 32,431 cycles in another laboratory to cause the same failure when testing an identical sample of

coated fabric. One instrument, using abrasive wheels, is specified in several specifications and from comments made at ASTM Committee meetings we know that most users believe that the abrasion wheels themselves vary so much that the test has no validity because of this variation. This is an example of a test which is designated in numerous specifications and yet there is no valid reason for its use except that abrasion resistance is thought to be important and the writer of the specification includes some abrasion test. The producer must make a material to pass the abrasion requirements and yet has no assurance that his test results will correlate with those of the consumer. The consumer has no assurance that even though the material meets the requirements of the specification that the end use will be satisfactory.

Subcommittee XXIV of D-11 ASTM has referred the problem of abrasion testing back to the Committee on Research as an unsolved problem because all evidence indicates that there is no correlation either between laboratories or between laboratory tests and actual service.

Adhesion of coating to fabric is an old test and one which the writer of a specification would specify without much question as to its reproducibility. To our surprise, however, the chairman of the Subcommittee XXIV task group on adhesion found that the correlation between laboratories was not good. The reason for the round robin was to determine the effect of jaw separation speed (2" VS 12" per min). No conclusions could be drawn because of the variation of test results between laboratories. Work is now in progress to determine the reasons for the lack of correlation.

Cold crack resistance is determined by at least nine different methods. Depending on the method used, there can be at least a 40°F variation in the reported failure temperature on the same stock by using different test methods. Therefore, extreme care

must be exercised in selection of the proper test. For instance, one of the automotive companies uses a falling weight on a specimen mounted on a foam rubber cushioned block. This is a reproducible test at a given temperature and we have reason to believe that it predicts the service life of a coated fabric for this particular seating application. However, we believe it to be of no value when used for an application such as tarpaulins because:

1. The temperature cannot be varied from -20°F because of the effect of stiffening or softening of the sponge rubber on the block.
2. The type of impact will not duplicate the whipping action developed when a tarpaulin is subjected to the wind action.

The test method described in MIL-C 4479 will give very reproducible results between laboratories. This test also eliminates variability of results between operators. The reason is that the samples are deformed at the same time and at the same speed in the same jig. We do not know how well this test compares with actual service. The use of this method should not cause any trouble because of lack of reproducibility. However, its use in a specification should be based on a comparison of test results with actual performance. These are examples of the care which must be exercised by the writer of a specification in specifying the type of test which will duplicate the conditions under which the material will be used.

The dimensional stability of a fabric subjected to processing conditions is one of extreme importance to some coaters. For instance, the use of a fabric with poor heat dimensional stability in a product requiring vulcanization will cause trouble. This fabric will either shrink or expand and can cause excessive damage to the finished product. In its way this test will evaluate the end item performance, because without it, there will be no satisfactory end product produced.

Sun aging is usually specified as so many days exposure but the trend is to be more definite. Some automotive companies are now specifying a certain number of Ultra-violet Sun Hours; this is a step ahead but it does not go far enough. We believe that in the future all sun exposure tests will be for a definite number of Langley units instead of a specified number of days or Ultra-violet Sun Hours. A Langley unit is one gram-calorie per minute per square centimeter. In practice the Ultra-violet Sun Hours are those hours in which the intensity of the sun is above 0.823 Langley units. This method is far superior to the method of recording all time exposed whether the day be clear or cloudy, but it still does not take into consideration the degree of intensity above 0.823 Langleys nor does it record any time below 0.823 Langleys. In an effort to be more accurate, work is being done to expose samples and record the exposure by Langley units. Mr. Cole Caryl of Desert Sunshine Exposure, Phoenix, Arizona is planning to present a paper at the spring meeting of D-11 ASTM. This paper, if presented, may be given at the meeting of Subcommittee XV Life Tests for Rubber Products, G. C. Maassen, Chairman. This paper will cover Mr. Caryl's work of several years duration on comparing exposure by Langley units in several areas.

In addition to actual sun exposure tests the writer of a specification has the choice of at least five light-aging devices. These are the RS Sunlamp, S-1 Sunlamp, XW Weather-Ometer, DLTS Weather-Ometer, and Fade-Ometer. So far as we know, none of these devices duplicate outdoor exposure but they do simulate the sun exposure. The Fade-Ometer test results are reproducible between laboratories if the machines are calibrated. This can be done with a standard fading paper which is obtainable from the National Bureau of Standards. Work in progress should soon supply a suitable means for calibrating the Weather-Ometers. It is our opinion that the use of light-aging devices is helpful in evaluating some

properties of a coated fabric. However, care must be exercised because they only simulate natural sun light and the results will not necessarily duplicate sun exposure.

The resistance of a coated fabric to deterioration caused by microorganisms can be determined by at least 11 different methods. Most of these methods call for controlled cultures. These tests cannot be conducted by most laboratories as they do not have the facilities for such work. To have this work done by an independent laboratory is quite costly. Therefore, unless the end usage of a product is critical to a certain type of microorganism, the specifying of this type of test will increase the cost of the product without increasing its serviceability. There is one test among the so-called mildew tests which can be conducted by most laboratories -- the soil burial test. This consists of burying the test specimens in a mixture of rich dirt and manure. It is not an easy test to pass because the fabric backing of a coated fabric is very readily attacked by this soil and unless the backing is adequately protected it is quite possible to have a 100% tensile loss after only two weeks exposure. Here again the writer of a specification should analyze the end usage and determine whether the material needs a special culture which will increase the cost of testing or whether a simple soil burial test will suffice.

The use of dielectric sealing and inlaying by the automotive companies has opened up another field of testing for coated fabrics and here again the fabric plays an important part, especially the finishing. The automotive companies are to be congratulated for establishing test methods and standards which are based on actual usage in their plants and also the end usage. They have set up tests which include arcing to prevent damage to their expensive dyes, bonding to insure that the bond between the parts will be sufficient to give satisfactory service, and inlaying to insure both

performance in their factories and good service life. In addition, they have checked the maximum temperature which would occur in a closed car on a hot day and have set up an aging test on the inlay sample to be sure that this heat would not cause separation of the bonded parts. In the course of their work they found that certain salts, which might be left in the fabric during the finishing and dyeing operations, adversely affect the dielectric properties so they also set up a power factor test for the fabric to predict potential trouble.

The use of dielectric fabricating methods has been very successful in the automotive industry so it is reasonable to expect that this will be expanded to many other uses of coated fabrics. From the producers viewpoint we can only hope that the writers of the specification for these other products will base their test methods and standards on the end use. The dielectric method of bonding can also be of use in bonding samples of cured neoprene-coated fabrics where the coating is too thin for the conventional method of adhesion testing. Two pieces of a cured neoprene-coated nylon fabric can be joined together by buffing the coated surfaces, cementing them, and pressing the two joined surfaces for 50 seconds at a dielectric voltage of 2950 volts. This method has resulted in some controversy between members of our organization. It is my opinion that it will give results more comparable to actual service because there is no solvating action on the uncured gum which, we believe, will occur when the uncured gum is washed to remove dust or talc and then cemented. This method is especially valuable for testing cured coatings where other methods fail.

Another factor which can influence the service life of a coated fabric with a dyed backing is the type of dye used. This is especially true when a sulphur color is used. Any residual acidity left in the fabric will gradually increase due to the combining of

the free sulphur from dye with moist air to form more acid. This, of course, will tender the fabric until it has become very weak. A simple pH test will alert the tester to potential trouble and an aging test using heat and steam such as described in Method 26-52 of AATCC will help predict the service life. We use both of these tests quite extensively in our laboratory. We have done this because of some very sad experiences in the past. As an example, we processed some fabric for raincoat use and this fabric subsequently weakened to the point where the coats were easily torn. This, of course, resulted in serious customer complaints and replacement of unsatisfactory garments.

Testing a Product -- New Test Methods. We are not always so fortunate as to have the material pass both the laboratory tests and the actual service tests. Sometimes the material looks good in the laboratory and fails when tested under actual service conditions. This is where new test methods are developed. Some are very simple tests and others are quite complicated.

The first step is to analyze the failure. In order to illustrate this phase of the work I will describe a problem with which we were confronted. A new type of tarpaulin was developed using a thin, yet extremely strong, nylon fabric. All tests looked good so a test tarpaulin was made and put into service. The service life of this tarpaulin was not satisfactory and an analysis of the failure indicated cracking and flaking of the surface coating along with some fabric failure. The first apparent step was to improve the low-temperature properties using a standard brittleness test to determine cold crack resistance. Soon it was apparent that this test would not predict service life. After some study of the problem it became apparent that the cracking was a combination of factors involving low-temperature resistance, adhesion, and dynamic flexing. As a result, a wind whipping test was devised in which the sample was

mounted on a truck cab and exposed to the elements along with the whipping action. This test produced the same type of failure that was experienced in service and has since been used to evaluate all new fabrics and coatings. It has also been used to evaluate production runs because the test is quite fast and simple to conduct. We expected temperature to be very important but have not found this to be an important factor. Therefore, we have been able to conduct this test in both hot and cold weather. In order for a laboratory test to duplicate the wind whipping test it would be necessary to construct a wind tunnel or other device with possible provisions for heating, cooling, and a variation of velocities. The maximum velocity, for instance, on a truck tarpaulin should be in the neighborhood of 70 miles per hour. For other applications the velocity would depend upon the end usage. We have experimented with a revolving wheel which seems to duplicate the truck wind whipping action quite well and believe that this may become a valid test method. So far no provision has been made for temperature control but this will be done later if found necessary.

Fig. 1 shows the type of installation we have used for the wind whipping test on a truck cab. This picture was taken while the truck was traveling at 50 miles per hour and shows the whipping action to which the samples are subjected. Fig. 2 shows the effect of this wind whipping on a sample after 325 miles with a maximum speed of 50 miles per hour. Fig. 3 shows a small laboratory machine for simulating the wind whipping action. A test device similar to this or possibly a wind tunnel will be a very valuable tool for evaluating any material which will be subjected to repeated flexing caused by wind or other factors and it may prove to be of importance for evaluating all kinds of fabric flexing.

The ASTM Books of Standards are primarily test methods but they do have a few specifications and one of these specifications is the

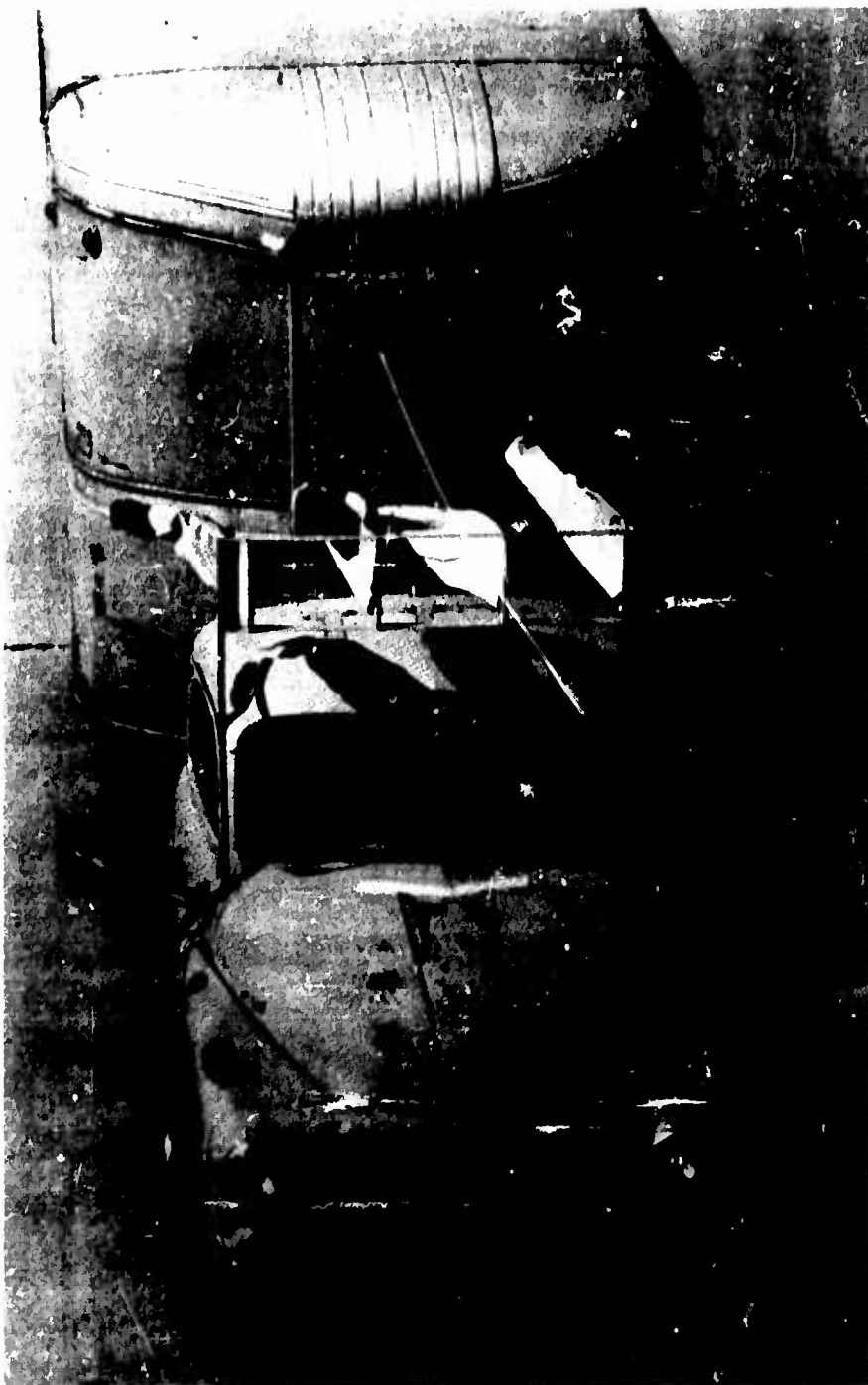


Fig. 1.

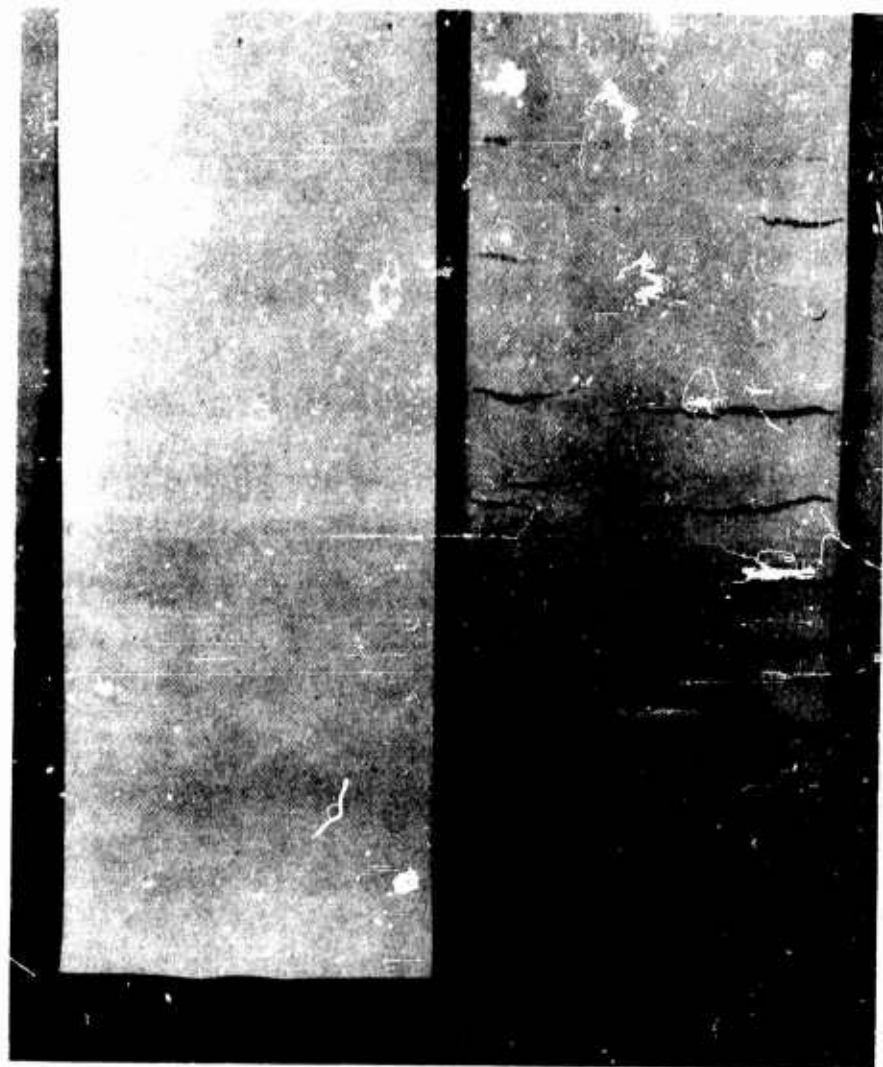


Fig. 2.

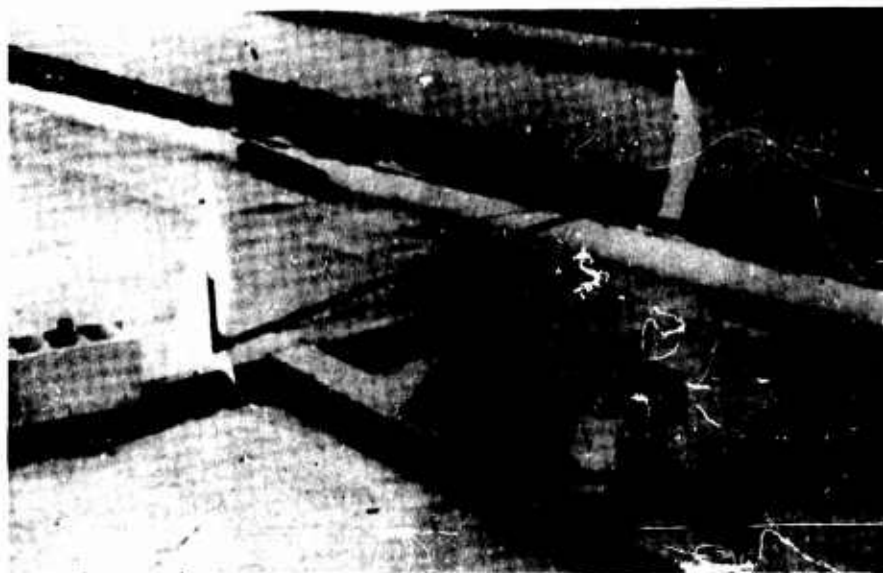


Fig. 3.

allowable limits for copper and manganese content of a cotton fabric for rubber coating. The test method lists a chemical test to determine the amount of copper or manganese in a fabric.

For some years we have used the spectrographic method for determining copper and manganese. This, of course, is a more expensive test method than the chemical method but it is very accurate in determining the amount of copper, manganese, or other elements which are present in the fabric. However, it is quite difficult to use this test or any chemical test where there are multiple colors such as in a striped fabric. Also, it is entirely possible for the purchaser of a fabric to reject it because of too high a copper or manganese content; yet, he can be rejecting usable fabric. It is well established that copper or manganese in some compounds or forms is not injurious to rubber. However, copper or manganese in other forms is very poisonous to rubber. There are, of course, other elements than copper or manganese which can cause bad aging of a rubber coating. After considerable experimental work we

developed what we consider a rather novel method of testing a fabric to determine whether it contains anything injurious to the rubber coating. We believe that the method which we use is superior to any chemical method because we are subjecting the fabric to a test which will be more nearly identical to that of service. The only difference would be that in service the compound is usually compounded to protect it as much as possible against the effect of the injurious chemicals. Our method consists of mixing a compound which contains no antioxidant and calendering this to a very close tolerance of $0.010" \pm 0.001"$. See Table 1 for compound data. This sheet is laid out on a piece of glass and is solvated with gasoline. Then the sample of fabric to be tested is placed on the sheet of rubber, while it is still wet with the solvent, and rolled lightly to press the fabric into the gum. This assembly is given a conventional vulcanization. After curing, it is put into a Fade-Ometer with gum side to the arc for 1 1/2 hours and this is followed by a 2 hour air bomb aging at 260°F with 70 lb air pressure.

TABLE 1
FORMULA OF RUBBER STOCK FOR INJURIOUS CHEMICAL TEST

	<u>Parts</u>
#1 Smoked Sheet	100
ZnO x 166	5.0
Laurex	0.5
Stearic Acid	0.6
Retarder W	0.1
G-Carbonate	15.4
Paraffin Oil	3.0
Blue UB6917	1.3
Captax (MBT)	0.94
Monex	0.05
Rubber Chem 710 (Naukatuck Chemical)	0.2
Sulfur	1.27

Along with the sample of fabric to be tested there are always two standards, one being a fabric which is known to be satisfactory and another one which contains an injurious chemical which is

known to have a detrimental effect on the rubber coating. When the samples are graded there should be no failure on the standard sample containing no injurious chemicals and a complete failure on the sample containing injurious chemicals. If the unknown sample or the sample being tested show no bad effect from the aging test, the fabric can be approved with good assurance that there will be no failure in the field. However, if the sample does fail then there is a serious question whether a compound can be made which will contain sufficient injurious chemical inhibitor to prevent failure in service. To illustrate the type of failure which occurs, Fig. 4 shows how the area subjected to the Fade-Ometer arc has completely deteriorated whereas the area not subjected to the Fade-Ometer arc is relatively unaffected. This brings up the idea for another type of a standard aging test which would combine heat and light, either simultaneously or at different times. It is a field which we have not investigated thoroughly but one which merits some work. In actual service, items are subjected to light as well as heat. A standard Geer aging, oxygen bomb aging, or air bomb aging will not predict the aging life of a given compound, whether it be on a fabric or otherwise, when the body of the material is subjected to considerable light. The effect of light is more pronounced on thin coatings or thin films.

Value of Investigating Actual Service Conditions. To illustrate the value of examining consumer-purchased items I will describe another one of our problems. We were receiving complaints from a mining company in the Southwest that our rubber-coated suits were not giving adequate service. Our examination of the returned garments indicated peeling of the gum from the fabric. Yet, our control tests indicated adequate adhesion of the gum to the fabric. A very faint odor was noticed although too faint to recognize. A trip was made to the mine and the answer was soon apparent because at

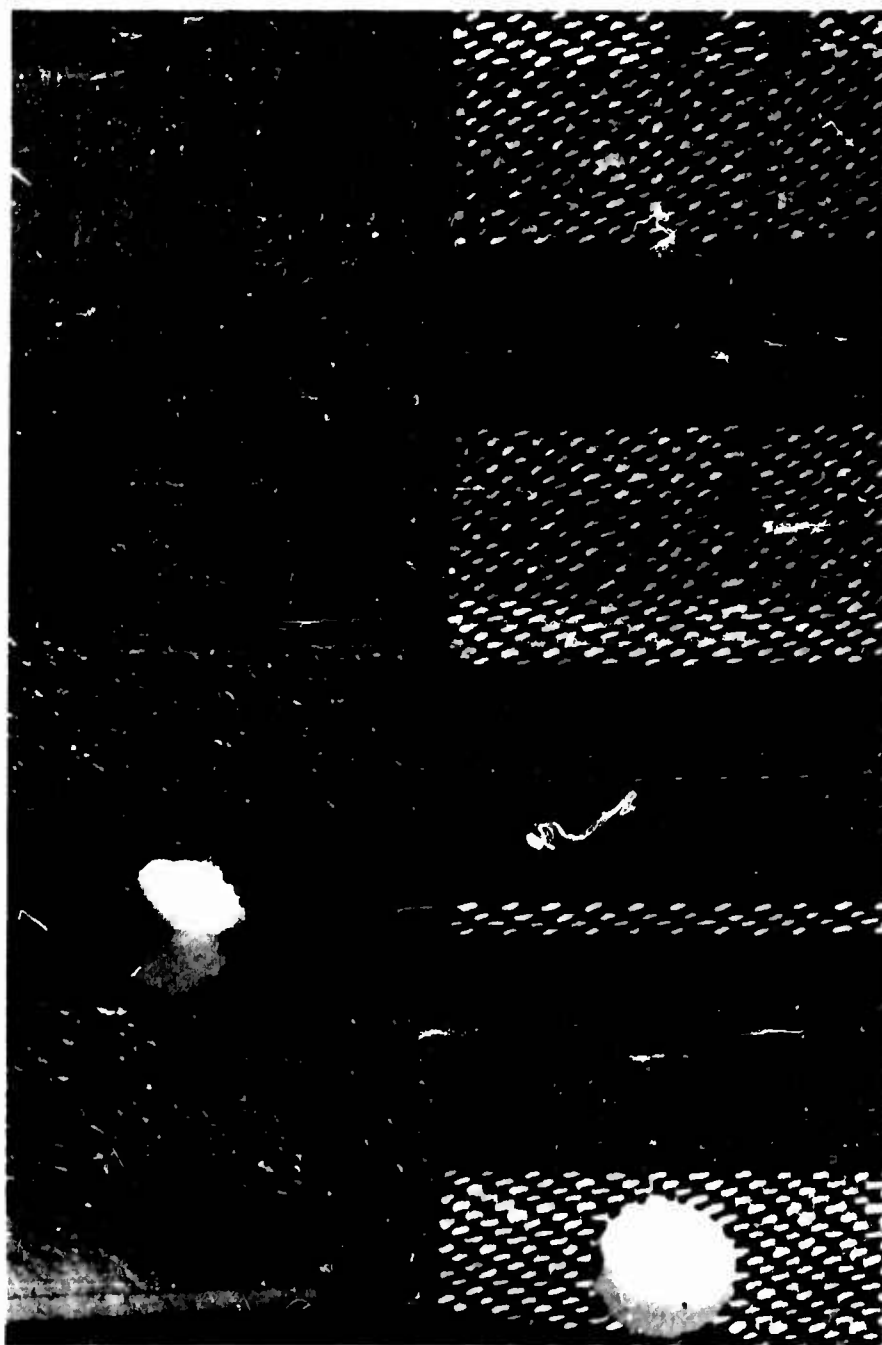


Fig. 4.

this mine each employee, during the course of his days work, would use an air operated jackhammer. All of the jackhammers were lubricated by oil injected into the air supply and the position of the hammer during the work was such that the hammer exhausted oil-laden air directly onto the suit. The oil loosened the gum from the fabric and this, combined with the wearing, caused the gum to peel from the fabric. A change from rubber to neoprene-coated fabric eliminated the trouble and resulted in a satisfied customer. Thus a critical look at the end usage resulted in a satisfactory end product.

Summary. Quite a few of the coated fabrics test methods have been discussed and we have covered only a few of the very many test methods which are available to the evaluator of a coated fabric. It is presumptuous for me to tell you what method to use, but in closing, I can give the following advice:

1. Use service tests or consumer-used material wherever possible to determine the suitability of a coated fabric for its intended use.
2. Base all physical tests on:
 - a. A study of the properties necessary to produce a satisfactory end product.
 - b. A study of the tests which will simulate the actual service conditions.
 - c. A study of the reproducibility of the test method in various laboratories.
3. Make sure that all pertinent tests have been included in the specification.
4. Eliminate any test which does not have a bearing on the serviceability of the product or cannot be duplicated in another laboratory.

Appendix

AVAILABLE TEST METHODS

<u>Type of Test</u>	<u>Method</u>	<u>Reference</u>
Abrasion	Stoll Flex	CCC T 191b
	Stoll Flat	"
	Stoll Edge	Automotive
	Wyzenbeek	ASTM
	Wyzenbeek Modified	Automotive
	Taber	ASTM
	Schiefer	CCC T 191b
	International	International
	Harvester	Harvester
Accelerated Aging	1 lb Block	MIL B 7110
	Closed Container	CCC T 191b
	Oven	ASTM
	Air Bomb	CCC T 191b
	Steam	ASTM
	Fuel	MIL F 5571A
	Alcohol	"
	Oil	"
	Heat Cracking	MIL C 8135
	Heat Resistance	Automotive
	Heat Sensitivity	"
	Hot Water	MIL B 1591
	100% Humidity	Automotive
	Resistance to	"
	Humidity	"
	High Temperature	"
	Deterioration	"
Acidity	pH Colorimetric	CCC T 191b
	pH Potentiometric	"
Acid Resistance	Red Fuming Nitric Acid	MIL C 12526
	White Fuming Nitric Acid	MIL C 12526
Adhesion	Seam	CCC T 191b
	Coating Solvent Method	"
	Coating Water	"
	Resistance	"
	Plied	"
	Strapped Seam	"
	Pendulum	ASTM
	Strip Method	Automotive
	Bond	"

<u>Type of Test</u>	<u>Method</u>	<u>Reference</u>
Air Permeability	Calibrated Orifice Falling Cylinder	ASTM CCC T 191b
Bleeding	Petri-dish Method Cements Method	Automotive "
Blistering	Ultra-violet Light	Automotive
Blocking	Oven Method	Automotive
Bow	Visual	ASTM
Bursting Strength	Hydraulic Ball Burst	ASTM ASTM
Cleanability	Stoll Grease	Automotive "
Cold Crack	Falling Weight Impact Pendulum 180° Bend 5 lb Roller 10 lb Roller Masland Creased 1/4" Mandrel 1/8" Mandrel	Automotive " " " " MIL C 15104C MIL C 7719A Automotive MIL C 8135
Colorfastness to Laundering	Launder-Ometer Wash Wheel	CCC T 191b "
Colorfastness to Light	Fade-Ometer Natural Light S-1 Sunlamp RS Sunlamp	CCC T 191b " ASTM ASTM
Colorfastness to Perspiration	Perspirometer Tube	CCC T 191b "
Colorfastness to Salt Water Soap Water Dye to Water Gasoline Dry Cleaning		" " " AATCC Automotive MiL C 171585
Colorfastness to Weather	National Weathering Unit Natural Sunlight Fade-Ometer	CCC T 191b " "

<u>Type of Test</u>	<u>Method</u>	<u>Reference</u>
Color Matching	Artificial Day Light Artificial North Sky Daylight Artificial Horizon Sunlight National North Sky Daylight	Automotive " " MIL C 20696
Crease Resistance	Angle of Recovery Cold Press	CCC T 191b Automotive
Crease Whitening	Pressure	Automotive
Crazing	Pressure	Automotive
Compatability	Pressure	Automotive
Crease Recovery	Vertical Strip	ASTM
Crimp		Automotive
Crocking	Crock-Ometer Wet Crock-Ometer Dry	ASTM ASTM
Corrosive	Resistance	MIL B 7110
Delamination		Automotive
Arcing Test Coated Fabrics	Dielectric	Automotive
Arcing Test Ink	"	"
Blistering	"	"
Bond Strength	"	"
Aged Bond Strength	"	"
Grain Retention	"	"
Inlay, Coated Fabrics	"	"
Inlay, Coated Paper	"	"
Inlay, Film	"	"
Power Factor, Fabrics	"	"
Dimensional Change		ASTM
Dimensional Stability		Automotive
Dye Stability		Automotive

<u>Type of Test</u>	<u>Method</u>	<u>Reference</u>
Elongation	Single Strand	CCC T 191b
	Cut Strip	"
	Grab	"
	Ravel Strip	"
	Ultimate	ASTM
Extractable Matter	Dead Weight	Automotive
	Chloroform	MIL P 10747A
Exudation		Automotive
Flammability	Normal	ASTM
	Intermediate	"
	Rapid and Intense	"
	7° Angle	MIL F 5577A
	Penetration	CCC T 191b
	Vertical	ASTM
	45° Angle	ASTM
	Rate Horizontal	CCC T 191b
	Rate 30° Angle	"
	Rate 45° Angle	"
	Resistance Horizontal	"
	Resistance Vertical	"
	Field	"
	Resistance Vertical	"
	Resistance 30° Angle	"
Flex and Fold	Retardant	ASTM
	Chrysler Flex & Fold Machine	Automotive
	United Flex & Fold Machine	"
	Studebaker Flex & Fold Machine	"
Flexibility	Tinius Olsen	MIL D 10860
	Navy Folding & Endurance	MIL C 15104C
	MIT	MIL P 10747A
Gauge		CCC T 191b
Grain Retention	Oven	Automotive
Hydrogen Permeability	Gas	ASTM
Hydrostatic	Modified Diaphragm	ASTM
	Pressure of Water Column	"

<u>Type of Test</u>	<u>Method</u>	<u>Reference</u>
Hydrostatic	Mullen Seam Suter	Automotive MIL P 3033b
Hydraulic Fluid	Resistance to	MIL C 19524
Ice Repellent Properties		MIL C 19524
Fiber Identification		ASTM
Impact Resistance		MIL B 1591
Injurious Chemicals	Rubber Aging Method Chemical Test	Not Standard ASTM
Laundering	Wash Wheel	ASTM
Leaching	Pre Wet Specimen Standard Method	CCC T 191b "
Length	of Cloth General Drum	CCC T 191b ASTM "
Lubricating Oil	Resistance to	MIL C 19524
Mar Resistance	Fisher Body Mar Tester	Automotive
Melting Point of Nylon		MIL C 19524
Mildew Resistance	Non Sterile Sterile Enriched Soil Suspension Mixed Culture Degration -- Bottle Degration -- Petri Dish Disfiguration Soil Burial Mineral Salts Agar Water Agar Glucose Mineral Salts Agar	CCC T 191b " " " " " " ASTM " " "
Moisture Content	Oven Balance Oven	CCC T 191b "
Odor		Automotive
Oil Resistance		MIL C 7719A
Ozone Resistance		MIL F 5577A
Permanence of Finish	Boiling Water	MIL C 8135

<u>Type of Test</u>	<u>Method</u>	<u>Reference</u>
Pliability	Fisher Body	Automotive
Plasticizer Migration		Automotive
Resistance	Hydrocarbons	"
Resistance	Fuel Oil	"
Volatility	Oven	"
Volatility	Activated Carbon	"
Salt Water	Resistance to	MIL C 15104C
Scrub	Hand Method	MIL C 15104C
Scuff	Wyzenbeek	Automotive
Set	Initial	ASTM
	Permanent	"
Sewability	Strength of Seam	CCC T 191b
	Sewing Qualities	MIT. C 7719A
Shrinkage	Oven	Automotive
	Dry Cleaning -- Cloth	CCC T 191b
	Dry Cleaning -- Garments	"
	Laundering -- Cloth not Cotton or Linen	"
	Laundering -- Cloth Cotton or Linen	"
	Laundering -- Mobile Laundry Method	"
	Laundering -- Washing Machine Method	Automotive
	Laundering -- Soaked	"
Sizing	Per Cent	ASTM
Slip Test	Machine Method	U. S. Rubber Company
Slipping Resistance	of yarns in cloth Seam Method	CCC T 191b "
Soilability	Stoll	Automotive
Spew	Oven	"
Spotting	Water	"
	Cleaning Fluid	"
	Lead	"

<u>Type of Test</u>	<u>Method</u>	<u>Reference</u>
Staining Resistance	Cements	Automotive
	of Embossed Material	"
	Perspiration (Petri-dish)	"
	Hydrogen Sulfide	"
Stiffness	Cantilever Bending	CCC T 191b
	Hanging Heart Loop	"
	Self Weighted Centilever	"
	Drape	Automotive
	Flex	"
	Clark	MIL C 12189A
	C M S	"
Stretch	Dead Weight	Automotive
Tackiness		"
Taste		MIL B 1591
Tear	Pendulum Impulse	ASTM
	Tongue	"
	Trapezoid	"
Temperature High	Effect on Flexibility	CCC T 191b
Tensile	Single Strand	CCC T 191b
	Cut Strip	"
	Grab	"
	Ravel Strip	"
	Wet	"
	Constant Rate of Load	"
Thickness		ASTM
Thread Count		"
Toxicological Agents	Mustard	MIL C 12189A
	GB	"
Toxicity		MIL C 12526
Twist		ASTM
Vapor Transmission	Dish Method	Automotive
	Cup Diffusion	MIL T 6396A
	Hot Cup Diffusion	Aeronautical
Water Resistance	Drop Penetration	CCC T 191b
	Dynamic Absorption	"
	Immersion Absorption	"
	Low Range Hydrostatic	"
	Pressure	"

<u>Type of Test</u>	<u>Method</u>	<u>Reference</u>
Water Resistance	High Range Hydrostatic Pressure	CCC T 191b
	Rain Penetration	"
	Water Impact Penetration	"
	Water Permeability (Hydrostatic)	"
	Spray Absorption	"
	Spray Method	"
	Static Absorption	ASTM
	Static Immersion	AATCC
	Suter Hydrostatic	MIL C 8135
Weight	Plug Method	ASTM
	Roll Method	"
Wicking	Distilled Water Method	Automotive
Width		ASTM
Wrinkle Resistance	Wrinkle Recovery Method	AATCC
	Roller Pressure	"
	Crease Recovery	
Yarn Ply		MIL C 8135

TECHNICAL SESSION NO. 4

Stanley Backer, presiding

SUPPLEMENTARY PRESENTATIONS

Chairman Backer: We have asked Mr. Shaller of Goodrich and Mr. Stuart of the Enjay Company to supplement Mr. Fritz's talk, covering those materials with which Mr. Fritz, in his activity at the duPont Company, was not directly concerned. In addition, Mr. Schafer of Weblon Corporation has been asked to discuss laminates, and Mr. Whitehead of the Celanese Corporation and Mr. Schumann of American Enka to comment on fibers.

The cooperation of these speakers is greatly appreciated.

CHARACTERISTICS OF VINYL AND NITRILE COATING MATERIALS AS WELL AS A LOOK AT SOME NEWER PRODUCTS

LAWRENCE L. SHAILER, JR.-- Received a B. S. in Chemical Engineering from the University of Illinois in 1943. The same year he joined the B. F. Goodrich Company and was closely associated with the process development and commercialization of vinyl latices and resins. In 1946 he joined B. F. Goodrich Chemical Company in Cleveland, Ohio, as development engineer in the product application laboratory. Following assignments as technical service engineer, sales representative, and product engineer responsible for the market development of hydrophillic materials he was appointed manager of textile chemicals sales development in 1957.

Fungus Resistance. Since the fungus resistance of polyvinyl chloride (PVC) is so outstanding, the fungus resistance of its compounds is usually a direct function of the particular plasticizer used in the compound preparation. The effect of various plasticizers

and the protective action of various additives have been studied intensively and reported in the literature. Much of this work originated from Quartermaster Corps activity following World War II and was based upon evaluation of unsupported film and sheeting as well as coated fabric. Through fabric pretreatment or use of fungus-resistant fibers (e.g., nylon and glass) satisfactory constructions may be achieved readily. The pretreatment of cotton fabrics with Copper-8 incorporated in a nitrile latex (e.g., Hycar 1561) has the dual advantage of extending fabric protection under leaching (weathering) conditions and providing a compatible anchor coat for subsequent vinyl coatings.

Gas Permeability and Moisture Vapor Transmission. Both properties are greatly influenced by the compounding additives used to adjust the processing and general performance characteristics. In the case of PVC the choice of plasticizers (primary and secondary), type, and concentration of loading agents have a major effect upon gas permeability and presumably upon moisture vapor transmission. Increase in loading appears helpful. Those plasticizers considered best for low temperature performance appear to give the poorest air permeability results. These are factors which underscore the necessity of careful compounding, compromise, and testing to reflect the exact end-use conditions.

Nitrile rubbers yield exceptionally low gas permeability properties. This has been a relatively unexploited advantage of this versatile class of oil resistant materials. It is not generally appreciated that high-acrylonitrile-content polymers such as Hycar 1001 yield gas permeability values equivalent to butyl rubber.

Most of the available permeability and moisture vapor transmission information has been collected on film or sheeting samples rather than on a coated substrate. While such information should be directly applicable to coatings; e.g., coated fabrics, consideration should be given to the method of manufacture. Fabric

pretreatment such as singeing, anchor coating, calendering, and others should be considered and their need appraised. The possibility of permanent type, compatible, warp sizing might be advantageous. These suggestions, most of which are at least partially utilized, are all aimed at minimizing the "wicking effect" of fibrous yarns.

New Coating Materials. The increasing emphasis on excellence of weathering properties and the continuing need for materials capable of satisfying higher service temperatures has focused attention upon Hycar 4021. This material, a polyacrylic elastomer, provides a highly satisfactory material for continuous service in the 300 to 350°F range and intermittent service at temperatures in excess of 400°F.

Where better than normal oil and/or ozone resistance are critical factors the use of a carboxylic nitrile elastomer such as Hycar 1072 is recommended. This material yields superior physical properties (including low temperature characteristics) when a combined zinc oxide and sulfur cure is used. It also has the additional advantages of enhanced compatibility with vinyl and phenolic materials although these have not been exploited in fabric coatings to any appreciable extent.

Estane VC, a linear thermoplastic polyurethane, possesses unique and necessary characteristics for industrial and military coated fabrics. This material is outstanding in tensile and tear strength and possesses excellent abrasion, solvent, oil, and ozone resistance. Since these properties are realized in the unvulcanized state, the complications of conventional (vulcanizing) urethane elastomers may be avoided.

BUTYL RUBBER IN PROOFED GOODS APPLICATIONS

STANLEY R. SHUART -- Graduated from the University of Miami in 1952 with a B. A. in Chemistry. After graduation he joined B. F. Goodrich Rubber Company, Akron, Ohio, and engaged in such activities as development compounding. In May 1953 he entered the U. S. Army, where he participated in development of protective clothing and gas masks in the Rubber Laboratory, Army Chemical Center, Edgewood, Maryland. In 1955, he joined Enjay Laboratories as Research Chemist handling technical service activities on butyl rubber. From October 1957 to the present time, he has been Technical Coordinator for Butyl Division of the Enjay Company.

Today, butyl rubber is employed in the proofing industry for a wide variety of applications, each taking advantage of one or more of the unique properties of this material. A few such applications are:

- Automotive Convertible Tops.
- Portable Swimming Pools.
- Rubberized Upholstery Fabric.
- Flexible Pipe for Irrigation Purposes.
- Canal Liners for Irrigation Purposes.
- Chemical Resistant Clothing.
- Rainwear.
- Air Mattresses.

The properties that account for the use of butyl rubber in these applications are as follows:

1. Ozone and weathering resistance.
2. Abrasion and flex resistance.
3. Impermeability to gases.
4. Electrical resistance.
5. Heat resistance.
6. Chemical resistance.
7. Tear resistance.
8. Non-staining and non-discoloring properties.
9. Cost.

As is the case with other elastomeric materials, compounding plays a very important role in determining whether or not the

optimum in properties is obtained. Often it becomes necessary to compound for a specific property such as chemical resistance at the expense of other desired characteristics. A few years ago some work was carried out in conjunction with the Army Chemical Corps to develop butyl compounds that were resistant to red fuming nitric acid and other rocket fuels. These butyl compounds are necessary for the fabrication of protective clothing. Compounds containing from 20 to 40 parts of polyethylene were found to have excellent resistance to red fuming nitric acid. The permeability properties of the butyl phase afforded resistance to migration of the acid through the coating, thereby protecting the reinforcement fabric. The chemically inert polyethylene maintained a tack-free surface. An all-butyl compound, after prolonged exposures to the acid, would develop some surface tack due to polymer degradation and render the protective clothing unsuitable for further use. A butyl-polyethylene blend, in blocking tests designed to measure tack, had a zero rating after the specified exposure times. This example indicates a case where optimum chemical resistance was required and was obtained; however, at some sacrifice of other physical properties. While on the subject of chemical resistance, it should be mentioned that it has been reported that the resin cure of butyl gives an outstanding compound with regard to resistance to many oxidizing materials. This type of cure system is covered in patents held by the U. S. Rubber Company.

The ability to resist ozone degradation and the ability to maintain physical properties after long exposures to general weathering exposures such as heat and sunlight are important factors for many applications. Butyl rubber has been employed for some very severe applications that illustrate these characteristics. In 1948 a program was initiated at the Utah Agricultural Experimental Station to develop a liner for irrigation canals and reservoirs. Butyl applied on fiberglass, nylon, rayon, and cotton was fabricated and exposed to the

elements in this application. Tests, after 8 years exposure, indicated that the butyl rubber had not degraded from the effects of sunlight and ozone. As a matter of fact, when samples were compared with newly compounded stock in ozone at 0.2% concentration, the new compound took 211 minutes before cracking while the old compound (exposed for 8 years) took 172 minutes before the first crack. This, it should be added, is within the experimental error of the test. In similar high ozone concentration tests, well-protected natural rubber and SBR stocks will only run about 20 minutes before complete degradation. These canal liners are still in use today (ten years after the original installation) and appear to possess their original flexibility, abrasion-, sunlight-, ozone-, and fungus-resistant characteristics.

Today, butyl is widely used in the wire and cable industry where the ozone concentrations are sometimes high and the ability to resist ozone cracking is very important. Samples of butyl insulated wire have been exposed in excess of ten years with no noticeable effects of ozone. Not directly related to the proofing industry but another example of butyl's ozone resistance is that it is now being used in automobile window channels around the front and rear windshields. A test was conducted for 70 hours in 50 parts pphm of ozone at 100°F comparing two commercial butyl compounds with a commercial SBR channel. The samples were bent around a mandrel so that the stress applied in some areas was very critical. At the end of this test, no visible ozone cracks in the butyl samples were apparent; whereas, in the SBR channel the cracking was so severe as to indicate a completely unserviceable channel. This type of cracking is similar to that which many automobile owners have noted around their own windshields.

Of course, the ability to withstand the effects of ozone is not the only requirement in many applications. The heat aging properties of all elastomeric materials are of great importance, especially

to the military. A comparison of natural rubber, SBR, and butyl in a standard heat aging test conducted at 260°F indicates that butyl retains approximately 95% of its original tensile strength whereas SBR degrades to approximately 60% of its original tensile strength after the 80 hours exposure. Natural rubber becomes brittle and hard at the end of 60 hours exposure. Elongation results from the same test indicate that butyl will retain about 70% of its original elongation; SBR, less than 20% after 80 hours exposure. At 60 hours exposure the natural rubber has lost essentially all of its original elongation. Standard compounds, designed for a degree of heat resistance, were used in these tests. The properties of these compounds can be varied by compounding and compounding techniques. Butyl is used in many high heat applications such as tire-curing bags and bladders and in the electrical industry where intermittent exposures of as high as 400°F have been encountered. Some development work is now underway to prepare resin-cure butyls and halogen-containing polymers to withstand even higher degrees of heat. The upper limit of butyl's performance in intermittent high heat applications is not known.

Of utmost importance in many proofing applications are the gas permeability properties of an elastomer. Butyl's use in the inner tube industry is well known. The familiar task of pumping up ones tires every week or every two weeks has ended because of the use of butyl tubes. An illustration of the gas permeability properties of natural rubber, SBR, and butyl is shown in Fig. 1. Besides gases, the impermeability property of butyl also applies to many chemicals that would normally penetrate elastomeric materials. This was illustrated by our previous discussion on butyl's resistance to red fuming nitric acid.

Also, the property of abrasion resistance is of great importance in proofing applications. Certainly, if a fabric is to be protected

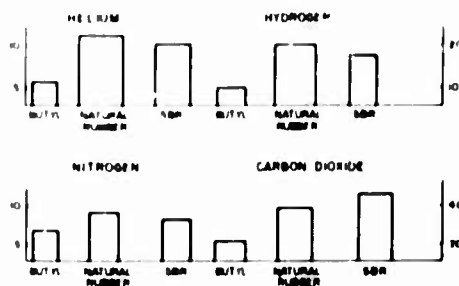


Fig. 1. Gas permeability of pure gum vulcanizates.
(Liters/sq m/10 mil/24 hr)

in general service the coating should not be abraded off so that the fabric is exposed. Most of the tests that have been conducted by the Enjay Laboratories on the effect of abrasion on butyl vulcanizates have been carried out on a Lamborn abrader. This type of abrasion is more characteristic of that encountered in tires, however, it does give a good illustration of butyl's resistance to abrasion. A determination of weight loss per kilometer of travel is made. In one such test, a comparison of a good SBR tread stock versus a butyl tread stock, the abrasion losses in grams per kilometer were 0.67 and 0.28, respectively. Because of this ability to resist abrasion, butyl is being employed in applications such as portable swimming pools, irrigation linings, clothing and furniture covers, and truck tarpaulin.

Of great significance to the proofing industry has been the development of a butyl latex that can be used to achieve high levels of adhesion to fabrics such as nylon and rayon. This is particularly important in tire construction where adhesion to cord for carcass durability is necessary. Table 1 shows a typical butyl latex formulation with the use of resorcinol-formaldehyde resin to achieve the necessary adhesion. This latex is available at a 55% total solids concentration and is used in this application without benefit of cure systems. It may be of interest for latex coatings and spread coatings for proofing applications. Development work is now underway in this area and preliminary indications are that it will have application in spread coatings as well as coatings of paper and

TABLE 1
BUTYL LATEX
DIP-MIX FORMULATION

<u>Ingredient</u>	<u>% By Weight</u>
Butyl Latex (55% T.S.)	27.3
Resorcinol	2.2
Formaldehyde (37%)	3.5
Water	67.0

TABLE 2
ADHESION OF BUTYL TO RAYON
lb/in.

<u>Treatment</u>	<u>RAYON</u>	
	<u>Filament</u>	<u>Spun</u>
None	6.25	15.5
Butyl Latex Dipped	15.75	33.0

for the production of laminates. Table 2 illustrates its influence on adhesion.

Another new polymer which may be of interest to the proofing industry is MD 551. It is a halogen-containing polymer which has some interesting properties of very high heat resistance, greater ozone resistance and chemical resistance, and the ability to cure somewhat faster than the commercially available butyl rubbers. In addition it will enable the use of a variety of cure systems including non-toxic systems, produce better adhesion, and afford a degree of compatibility with highly unsaturated polymers.

THE LAMINATE STRUCTURE

DAVID H. SCHAFER -- Graduated from Case Institute of Technology in 1951, with a B. S. in Chemical Engineering. He attended Naval OCS in Newport and spent three years on active duty. He joined the Textile Fibers Department of the duPont Company, Industrial Merchandising Section, in 1956, where he worked on the development and application of synthetic fibers for conveyor

belting and coated fabrics. In February 1958, he joined WEBLON, Inc. and S. L. Chambers Associates as manager of industrial sales, responsible for industrial applications of vinyl film and vinyl-fabric laminates.

Basic Structure. What is a laminate? The lamination I will discuss is a three ply combination of calendered film and woven fabric of synthetic fibers. It is a new type of fabric and one which has received more attention in the past two years. The majority of the basic ideas and theories in these laminates are not new. For years producers have been combining multiple plies of fabric, paper, wood, and foil (by hydraulic press and continuous roll methods) in very much the same manner being followed today in the manufacture of vinyl laminates.

With the advent of vinyl resins, plasticizers, and adhesives, the technique of calendering film was developed. At first, the vinyl film was laminated to cotton fabrics where the proper heat application would marry the two into a unit. With synthetic fiber fabrics this would not work so a different approach was devised. Two layers of vinyl film heated to a tack are sandwiched around the fabric (a scrim or open weave fabric, such as a 20 x 20 construction of 220 denier Dacron, plus an adhesive) to form a unit structure by 1. contact adhesion through the interstices of the fabric, and 2. direct adhesion to the synthetic fibers. Because a calendered film is utilized, the resulting product offers the advantages of a homogeneous coating, a coating of even thickness, and one that is free from solvent holes. Flame resistance, aging, and low temperature properties are built in on the calender.

At the present time, in order to achieve the necessary adhesion, a scrim or open weave fabric must be used. However, as lamination technology improves it most likely will be possible to laminate film successfully to a standard coating fabric; i.e., a 40 x 40 construction of 210 denier nylon.

Lamination Process. The lamination process is very simple. It requires two pressure rolls and heat to combine the film and fabric with an adhesive into a unit structure. The fabric can be combined in one of two ways; 1. by laying-in the film one side at a time, or 2. by combining both sides in a single operation. But the combination of heat, pressure, adhesive, and film component is a critical one. The nip roll, which consummates the bond under considerable pressure, may be a polished or an engraved roll -- the engraved roll imparting a surface texture to one side of the finished fabric. In addition, the film may be printed, usually before lamination, to provide practically any desired pattern such as stripes or floral patterns. Another method of achieving a stripe is to laminate vinyl strips to the fabric.

Adhesion. This is the critical part of the combination. Will it stay together as a unit under actual use? The industry has come a long way in the past four years in this direction, as will be discussed later in end use testing.

Normally everyone likes to measure the adhesion of a fabric whether the fabric be coated or laminated. But can anyone relate this value, in lb/in., to actual use? Very seldom, except in general terms. In measured value, a good laminate will have from 8 to 25 lb/in. It is important that the test be conducted fairly. For example, if a solvent is used in the test method, it is liable to reduce the value. Likewise, if heat is used, the adhesion is likely to be improved. The best method is to strip the coating without solvent or heat. This can be very difficult at times, particularly if a very soft film is used which has a lower tensile strength than the value of the adhesion.

Components. The majority of laminates produced are a combination of vinyl and nylon. However, many other combinations of the components below are or could be produced, depending on the properties that are desired.

Film

1. Vinyl chloride
2. Polyethylene
3. Mylar (polyester)
4. Vinyl fluoride
5. Polyurethane

Fabric

1. Nylon
2. Dacron
3. Fiberglass
4. Polyethylene
5. Fortisan - Rayons

Physical Properties. Tensile and tear strength will vary with the base fabric. With existing nylon base fabrics this will vary from 105 to 300 lb/in. (grab) in tensile and 20 to 65 lb in tear strength. Representative data for a nylon and Dacron laminate are listed in Table 1.

TABLE 1

	<u>Nylon</u>	<u>Dacron</u>
Base fabric construction	23 x 23	20 x 70
Yarn	210 denier	220 denier
Base fabric weight	1.4 oz/sq yd	1.4 oz/sq yd
Koroseal vinyl film	10-mil total	10-mil total
Total fabric weight	12 oz/sq yd	12 oz/sq yd
Breaking strength, lb-grab	145 x 145	105 x 105
Strength retention, after 40,000 impact folds	95%	95%
Burst strength (Mullen)	225	225
Tear strength, lb	25 x 25	20 x 20
Dimensional change at 212°F	2%	0
at 0 to 100% Relative Humidity	2%	0
Adhesion	Guaranteed against delamination in all recommended uses	
Flame resistance	Self-extinguishing	
Fade-Ometer, 500 hours	No significant color change	
Mildew resistance (ASTM D 684-T)	No visible growth	
Low temperature properties	Special low temperature Koroseal formulation	

End Use Testing. A few years ago the impression formed by many was that coated fabrics were invincible, or nearly so. This caused many a headache, because coated fabrics did fail -- sometimes. Fabric quality and fabrication have improved vastly to eliminate

part of the problem. The remainder is a matter of function and economics. Coated or laminated synthetics are used because they perform a function or functions better than other existing fabrics. This may be color, waterproofness, resistance to mildew, or others. Often it is simply lighter weight while maintaining adequate strength.

What is the proper fabric for a particular end use? There are and will be many. Each customer may prefer a different fabric, each of which will perform satisfactorily -- much the same situation that exists with cotton fabrics today. Often it boils down to how much the consumer wishes to pay. But there are minimums that should be watched. For instance, in a laminate where the yarn is cut from 210 to 140 (nylon) the saving is about 6¢/yd; for most uses this is hardly worth the decrease in strength that results. And, for continued outdoor exposure, what gauge film should be used? In thinner films plasticizer migration is much greater percentagewise. I normally recommend 5 mil film, a minimum of 4 mil.

After 13 months of continuous exposure at the Florida testing station of a large retailer, two awnings have performed very well. Color remains unchanged, flexibility is unchanged, high winds have failed to tear either fabric, a determined effort caused no delamination, and mildew has not formed. The test is still in progress. Both fabrics are Weblon-Dacron laminates, 6 x 4 mil vinyl on a 20 x 20 Dacron base fabric.

COMMENTS ON FIBERS

WILLIAM WHITEHEAD -- Received his education in London, England. He was employed as a Chemist with British Celanese Ltd., Research and Development, in the early production of acetate yarns. He joined the Celanese Corporation of America in 1924 as a Chemist and is at the present time Technical Consultant, Sales Department, Fibers Division. He was associated with the development of the Fortisan

Process, its products and their application. Mr. Whitehead is a Fellow of the American Institute of Chemists and a Fellow of the Textile Institute (Great Britain).

I have listened with a great deal of interest to this matter of fabrics and fiber in conjunction with coating. There is one little variance we have in the concept which is based on sound practice not only on laboratory experiment. With high modulus yarns of limited elongation, like Fortisan - I do not limit this to Fortisan - we do not use low twist yarns in a coated structure if we wish to obtain high and balanced strength and tear resistance, warp and filling. A very simple reason is involved; the coating tends to penetrate between the filaments more so in the case of the filling, preventing the filaments from acting together against strain and tear. Therefore, it is better to use some twist. For Fortisan 36 in 800 and 400 deniers, 3 turns of twist are usually adequate. In ordinary Fortisan, which is supplied in lower deniers, from 30 to 300, normally 2 1/2 or 3 turns are adequate. I assure you it is a fact that these fibers do not obey the rule that the greatest strength is obtained from zero twists. I do not want to get into a controversy with anybody as to the cause of this fact. The fact remains that each of these yarns has an optimum twist for maximum strength. If you take ordinary Fortisan, the square root of the denier multiplied by the twist should equal approximately 122. With Fortisan 36, the square root of the denier multiplied by the twist should equal 85.

There is one other thing that might interest you in coating. It is comparatively new with us although we have done some work on it in the past. One item the Quartermaster is looking for is a fabric that does not melt, the reason being that melt-burns on the human body must be avoided. A combination of Fortisan and cotton ply with a very simple twist is being used both in coated fabrics and

in proofing ducks - impermeable fabrics - ranging from 4 oz up to fabrics of the order of 11 or 12 oz. I mention this because I think it will be of interest to coaters. The two fibers have substantially the same elongation at the break and therefore there are advantages in strength addition.

We are temporarily using this formula: The Square Root of the total denier multiplied by the twist equals 200. This is an ordinary sewing thread twist. The residual twist in the cotton is not enough alone to hold it together, but in the ply, the strengths add. The fabrics are interesting - they go through ordinary cotton techniques for coating, proofing, and fungicides. In general, we can say that in 50/50 ratios, Fortisans/cotton, we have fabrics of balanced strength and tear resistance at least equal in physical properties to cotton ducks and sheetings of double the weight. We don't claim fantastic properties but these are quite interesting.

In the past there has been some criticism of Fortisan in connection with the inability to dye to the same shade with cotton. Mr. Fred Fortess, one of my associates, and his co-workers have finished a very fine piece of work on union vat dyeing with very simple procedures. It does not require any exceptional processes or dyestuff. So, that problem is licked.

One final thing; there are certain rules that have to be followed, which we found out when first developing coated Fortisans. One is that you scour down the fabric to 0.5% or less extractables. We prefer going down to 0.1% which can be achieved very easily. This provides the maximum natural adhesion. Before you coat, dry the fabric. We have found that the presence of moisture in the fiber, during coating will detract from adhesion seriously. We go down to to approximately 2% Moisture Regain. Don't forget that all cellulose fibers at 2% Regain or less are vulnerable. They become quite brittle.

COMMENTS ON FIBERS

O. DOUGLAS SCHUMANN -- Was educated at Tulane University (BBA) and New York University (MBA). Mr. Schumann has worked in the textile industry since 1947, in cost accounting, industrial engineer, production, sales, and market development capacities. He has worked with Lane Cotton Mills, Pomona Manufacturing Company, Morgan Cotton Mills, U. S. Rubber Company, Textile Division, and is presently employed by American Enka Corporation.

We have heard many comments about the use of synthetic fibers but I don't think anyone has gone into the use of viscose rayon. Some comments have been made about the possible use and, in passing, I don't want to miss the opportunity to have this put in the record -- that we, as a company (American Enka), are looking into the possibility of the use of filament high tenacity viscose types for this end use. I agree with what Mr. Whitehead has said about cellulosic fibers, especially in regard to predrying treatments. I'd also like to mention that we have approached the filament problem from a different angle. Rather than introducing twist, we have attempted to determine the effect of filament denier. We have found that a very definite effect is registered by varying the denier per filament. The fibers selected for the end-use should be engineered for that particular property.

In many cases with the fabric design identical, we have found that the fibers with variation in denier per filament showed a marked difference in their properties (greige fabric), but after coating the differences have been reversed. So, that's a very definite point that should be considered in the use of high tenacity filament.

In addition, some properties to be achieved in the final coated material, constructed of other synthetic fibers, must be based upon the fabric pretreatment prior to the coating. We have found

preliminary indications that such properties can be achieved by compounding the coating and there is no necessity for pretreating the fabric to achieve these end results.

Also, I would like to point out that there are a few properties of high tenacity viscose that do warrant some consideration by this group. They do have the advantage of having possibly the lowest cost per unit strength of any material. The viscose producers, in this country especially, are constantly improving the strength of their fibers.

In coating these fabrics, you will find that the pull down in width and loss in square yardage is more proportional to what you would expect in coating cotton fabrics than in non-cellulosic fabrics. We have coated 42" goods, two sides, lightweight coatings; 3.4 oz goods with an add-on of 6 to 7 oz equally distributed on either side and found that the finished goods were 41" in width. I would like to say to the Armed Forces that in times of national emergency that there are a number of end uses that are going to be consuming non-cellulosic type of synthetics. Quite possibly, cellulosic type synthetics may be a ready solution to their problem of availability since they (cellulosic materials) will be readily available.

Just a few other comments. We have attempted to do some work with viscose rayon fabric to determine the minimum construction with different deniers and square weaves. We feel we have enough information available at this time that we can take a number of fine denier fabrics and tell you, in different weaves and patterns, what the approximate construction should be to obtain enough fabric density so it can be coated.

Possibly high tenacity viscose can offer some advantages to the laminating trade as well. We have attempted to have one particular tarpaulin fabricated from this material and, even though it was

fabricated for a stationary type of application, we wanted to give it a very harsh test. We tested it on a truck for a number of winter months in the mountains of North Carolina. The tarpaulin was returned to us with large holes in the vinyl but with the fabric intact. This was odd since everyone feels that this viscose rayon has low wet strength. We found that the failure of this tarpaulin was due to flaking and cracking of the vinyl film which had pulled away in adhesion failure. The rayon scrim within the area encompassed by the failure in the film was not damaged visibly. So, we have arranged for continuation of this test on a stationary tarpaulin until complete failure. This exposure has been underway for approximately a year now and we expect that it will continue for some time.

DISCUSSION

Chairman Backer: We have a number of questions that have been submitted in writing. Questions will also be welcome from the floor.

The first question is directed to Mr. Ross from M. S. Moulton, Santa Barbara Plastics. With reference to the Air Force requirement of opacity in lightweight coatings, is there a possibility of use of vapor deposited metal in combination with other coating materials?

Mr. Ross: Yes there is a possibility. The vapor deposition of aluminum, primarily, is what we are looking at now. We have some samples which are being prepared for thermal evaluation. They will be available within the next 60 days to permit evaluation of whether they will meet our requirement for thermal and light transmission.

Chairman Backer: Question for Mr. Ross from Mr. Ernest H. Pagliatro, Connecticut Hard Rubber Company. Regarding the Sunshade Fabric, the present 20 oz fabric is too heavy. Has vacuum deposited aluminum on one side of glass fabric with white silicone on opposite side been evaluated? With the present reflective curtain, is all heat reflected? How much is transmitted? Is this the same type curtain used for protection against nuclear radiation?

Mr. Ross: We now have a fabric with aluminum on one side and silicone rubber on the other side. The aluminum will be exposed to the heat; however, I believe both sides will be evaluated. It is, primarily, a matter of reflecting all of the heat. Some heat does get through but not enough to affect the pilot underneath. The transmission has been less than 1 1/2 percent. Does that answer the question?

Mr. Pagliatro: Is that the same type curtain used for thermal radiation?

Mr. Ross: We have no requirement for reflecting or protecting for nuclear radiation in aircraft.

Chairman Backer: Next question from L. L. Heffner, North Carolina State College. Bob Grubb has reported unsatisfactory performance on natural weather exposure of all the synthetic-fibers coated fabrics which he tested. You (Mr. Ross) report satisfactory performance on coated synthetics for some of your end uses. Please comment on the apparently different conclusions you (Mr. Ross) and Bob have reached.

Mr. Grubb: I think I can save you a little difficulty there. The reason for the materials being unsuitable was not because of their weather characteristics in all respects but because of a lack of adequate fire resistance. Possibly that's the basis for that apparent contradiction.

Chairman Backer: Another question for Mr. Grubb: Why is the weight of major importance for canvas uses on naval vessels?

Mr. Grubb: It's essentially because of the difficulty in handling. That would be true with a lot of the topside tarpaulin and covers, and things of that sort. Some of these items are quite bulky and, especially after wetting the weight is considerable. It's just a generally more convenient method of handling the item. Of course, there are other considerations besides trying to come up with a lightweight material. There are other desirable properties they hope to achieve. But, the lightweight factor is desirable for ease of handling.

Chairman Backer: Mr. Ross, this question is from Mr. R. L. Holmes of Raybestos, Manhattan. What definition can you give us as to "thermal resistant requirements" for testing thermal resistant barrier coated fabrics? What temperature? How long?

Mr. Ross: Actually, I think the dimension of 4,000⁰F -- when you get beyond that you get into a classified area. As to how many

seconds involved, all I can say is if you are interested in this area and have a proper security clearance, visit us at Wright Field and we can talk about actual requirements. Other than that, if you have materials that might be of value with respect to thermal and light transmission we will be glad to test them at the base.

Chairman Backer: Bill Corry, this question is from Dr. Fred Fortes of Celanese Corporation. Has anyone developed a coated fabric of tear strength equal to or greater than the original scoured fabric?

Mr. Corry: I don't know of a case where the tear strength of the fabric is greater after processing. In all of our experience it has been reduced. One of the ways of increasing tear strength in uncoated fabrics is to treat it; for example, with a water repellent treatment. In limited trials with coated fabrics we found the water repellent treatment was unsuccessful in improving tear resistance. It might be possible to put on some type of treatment to improve tear after coating but you would not get the obvious results that you get with simply lubricating the fiber in the case of uncoated fabrics.

Chairman Backer: The next question: Will very elastic films permit greater realization of basic fabric tear strength?

Mr. Corry: The answer is, as the film becomes more stretchable the modulus is lower. Unless extremely low, as in rubber, the tear strength will improve appreciably. The difference between the PVC and butyl rubber illustrates the point. The tearing strength of the butyl rubber is normally considerably greater than the PVC which has a much higher initial modulus.

Chairman Backer: Do any coating films have greater tear strength than fabrics alone?

Mr. Corry: I don't know of any. Mylar films have quite a high tear strength and if they are thick enough, you might find a mylar film that has a higher tear than a given lightweight cotton fabric,

but in general, I think not. The reinforcing action of the fabric always improves the film tear strength, especially the tear strength.

Chairman Backer: The next question is: Do you know of any coated fabric now being made which has improved the strength by means of lubricating the yarn?

Mr. Corry: I don't know of any. It's something that might be possible. As I mentioned before, some rather primitive trials were made that didn't give us that result. We didn't get a loss but we had no appreciable improvement.

Chairman Backer: I have a question from Mr. Morrow, AFRCR. It pertains to the loss of tensile strength using the following knots on cordage: overhand, 55%; square, 50%; bowline, 40%; and clove, 35%. Is this sort of evaluation fairly accurate?

Mr. Corry: I don't know. We leave the knots pretty well up to the weavers. All we do is complain about them.

Chairman Backer: The next question. Is this tensile strength figured without a knot? Presumably, it is.

Mr. Corry: Right.

Chairman Backer: Now, for Dr. Kennedy. This question is from Sy Hyman, Herculite Protective Fabrics. The question is: Along with the variety of new coated fabrics being introduced, there come about the concomitant needs of new fabrication techniques. What are the current military agency facilities available for fabrication and seam research needed to develop and more fully adapt advantages offered by coated fabrics to the wide variety of military applications? Where are these facilities located?

Dr. Kennedy: We have done quite a job on seam research in the Textile Division over the last ten years, primarily, with sewn seams. Dr. Thomas, on the other hand, has been concerned with coated fabric application and seam formulation and has done work in that area. We have spent approximately 11 years on this project and

to two -- the two of us, we'd be very happy to address ourselves to any solution you have to offer. Isn't that correct, George?

Dr. Thomas: Yes.

Dr. Kennedy: I can't speak for the other services but I think the work in this field is fairly well known.

Chairman Backer: The next question: Dr. Kennedy said that the seams in coated nylon fabrics had a tendency to tear. How about a lock stitch and a felled seam?

Dr. Kennedy: I don't believe that any seam makes a great deal of difference. If you reduce the number of needle-holes you, of course, will obtain an improvement because the condition is essentially one of weakening the fabric. It is allied to the whole subject of seam efficiency on which we have done a great deal of work. If you are interested in this subject, contact Mr. Frederick or me for further information. It is a question of puncturing the fabric and weakening of it at the particular location. I don't believe any particular seam would make any difference although there is a possibility of improving the performance by reducing the number of stitches per inch.

Chairman Backer: A question now from Mr. Painter of Johnson and Johnson. Can you indicate any way in which non-woven fabrics are being used or considered for use in your fabric requirements? I presume this has to do with coated fabrics, does it not?

Mr. Painter: Yes.

Dr. Kennedy: I can't really answer that. Dr. Thomas, I think, can answer that. As far as uncoated fabric is concerned, we have great difficulty determining any place where non-woven fabrics would have applicability to our requirements. Mr. Shurtleff, is there anything you are doing on non-woven?

Mr. Shurtleff: The work we are doing currently on non-woven fabrics has to do primarily with lightweight tentage. We are

considering laminates with films such as pigmented polyethylene which will have a degree of resistance to deterioration by ultraviolet and the new mylar films. We have not observed enough initial increase in tear resistance of the uncoated non-woven fabrics to assure success of the development.

Chairman Backer: One more question from Mr. Heffner: Are coated fabrics made of synthetic fibers such as nylon and dacron, which melt at flame temperature, safe to use for housing men?

Dr. Kennedy: That's a rather difficult question to answer categorically. At the present time we avoid the use of these materials in our medium size, general utility tents. During the war a coated fabric was used in the Tent, Mountain, Two-Man. It was rationalized that the lightweight requirement was of prime importance. The chief danger in this small tent and in larger tents used for sleeping is fire resulting from overturned stoves and spreading of burning gasoline. In large maintenance tents, in which men work and not sleep, it is felt that the men can evacuate in safety in case of a fire. Essentially, our thinking is that tents for sleeping purposes should not be a fire hazard because the men would not be able to rouse themselves fast enough to get out safely. Considering the technology as we know it today and the fire resistance available in coated fabrics today, we would rule out the use of coated fabrics, at this time, for a tent in which men will sleep. If a substantial improvement is realized in the fire resistant characteristics and other properties of these fabrics, we would feel differently about them for this particular use.

Chairman Backer: Mr. Holmes asks: Have the new silicone water repellent treated fabrics any use as lightweight tarpaulins, tents, and other end items?

Dr. Kennedy: I can only say that while we are open-minded, I believe our technologists would say that we have not yet seen any

silicone water repellent treated fabrics which are equal in characteristics to other non-durable treatment for cotton fabrics which we are already using. I am pretty sure that is our position. There may be some treatments that have not come to our attention. We do use water repellent and fire resistant treated fabrics for the smaller tents.

Chairman Backer: Another question from Mr. Holmes: Does an aluminum coated surface reflect body heat back to the body?

Dr. Kennedy: I can only refer to articles by Drs. J. H. Newburgh, Lyman Fourn, and Milton Harris which appear in "Physiology of Heat Regulation in the Science of Clothing," a report on the work of the Committee on Aviation Medicine made during the war. In this book, unfortunately, out of print, there is a statement to the effect that for the case of body surface heat, the amount reflected back by an aluminum-covered surface is negligible. I have seen no data which would reverse that position.

Chairman Backer: Mr. Lonsdale, wonder if you would present that short remark you jotted down for me? Mr. Lonsdale, British Nylon Spinners.

Mr. Lonsdale: I have been listening to a lot of the discussion on the applications of proof cloth which are reproduced, to some extent or other, in England. There is one application which is, as far as I know, unique to England at the present time. It might be of interest to you.

This concerns the use of flexible containers for the transportation of liquids, particularly liquids with specific gravities less than one, or the transportation of liquids through the seas. Work has been going on at Cambridge University on this project for about two years. The latest container was tested last week and the week before in Southampton waters. The latest container is made of proof nylon fabric. It is very long and thin. These containers are called

"dragoons", rather serpent-like which distinguishes it from the "whales" which, I believe, are being developed over here and used in my country for the static storage of liquids. These "dragoons" are 100' long and 5' in diameter. They contain 40 tons of kerosene which is ten thousand gallons -- 10,000 Imperial gallons.

The particular one tested in Southampton waters last week out-rode many gales. It can be chained to the quay-side without damage. The weight of the container is 2,300 lbs; the weight of the nylon part of it is 200 lbs; the estimated cost is \$8,000. This thing, so far, has been quite successful. It has had no breakdowns in Southampton waters. The object, of course, is to transport liquids more economically than the conventional barges. When the "dragoons" are empty, they can be transported very easily, particularly by air.

Two of the principal difficulties in designing "dragoons" are 1. to obtain an impermeable container which won't break down at all and 2. to make a long container which won't snake in the water. These two problems have been overcome in the "dragoon" tested last week.

Larger "dragoons" are being designed: 200' long at an estimated cost of \$16,000; 300' long, 15' diameter, at an estimated cost of \$30,000.

I thought you might be interested in this development, particularly as some people are beginning to think these containers might be used for underwater towage.

Chairman Backer: A question from L. G. Rainhart of the Sandia Corporation: Are there any coaters presently offering urethane coated nylon materials? If so, whom?

Mr. Fritz: I know of just one and that is the F&F Department of our Company, duPont. But, I am sure that there are others who are combining either solid or fluid urethane with various textile materials.

Chairman Backer: Question from J. M. Holaday, B. F. Goodrich: What plasticizers are recommended to improve low temperature flex of urethanes?

Mr. Fritz: Well, by and large, the same type of plasticizers used in other rubbers are perfectly adequate, the phthalates and phosphates.

Chairman Backer: A question from R. W. James of the Chemical Rubber Products Company in Beacon, New York: Do you have any data on the shelf life of uncured Viton A? (Coated on glass?)

Mr. Fritz: We have no specific data but I think I can answer it in a little different fashion. The shelf life of uncured Viton compositions cured at a normal manner with carbonate curing systems is quite long because the carbonate does not become active until you reach temperatures of about 250°F. In our laboratories we have uncured Viton compositions on hand for at least 60 days with no change in properties or cure rate.

Mr. James: At what temperatures did you keep those stocks?

Mr. Fritz: Those were kept in our laboratories at temperatures of probably not over 90°F. We have also run some tests, Mill Scorch Tests, wherein we keep pieces of uncured compounds on hand in a solvent at 120°F for a period of time, and then put them back on the mill and check them and the scorch life. I am guessing now, but I feel certain that we have had very good luck after a month under those conditions.

As I mentioned, there is every reason to think that due to the fact that these curatives are very stable up to 250°F, the uncured shelf life should be quite good. Does that answer your question?

Mr. James: Yes.

Chairman Backer: A question from J. Booth: Have acrylic resins been investigated as a protective film over nylon and dacron fabrics? If so, what are the major advantages, disadvantages, and problems associated with an acrylic coated fabric?

Mr. Fritz: I don't know. Perhaps there are other people in the room who would comment on this. Anyone from Rohm and Haas or any other resin manufacturer who wants to comment?

Mr. Shaller: (Goodrich) There's very little done on nylon and dacron; most of the acrylics are on cellulose. I am contradicting here slightly. There's been a bit of acrylics in blended systems, especially in non-woven fabrics. Acrylics are being combined with nylon; blends are stepping up in activity for apparel, non-woven uses but not for impermeable coatings.

Voice: How is the life degradation of those?

Mr. Shaller: Life degradation properties are good. That's one of the finer accepted properties of acrylic esthers. There's a difficulty with the alternate effect of washing and UV exposure. That's what you had reference to, sir?

Voice: Yes.

Mr. Fritz: Thank you, very much, for helping me out.

Chairman Backer: Another question: Will Mr. Fritz enlarge upon the retention of low temperature flexibility by Hypalon low temperature formulae on prolonged weathering? This is from Mr. S. C. Frowde, IC Limited.

Mr. Fritz: I suspect he is making reference to the low temperature formula shown on one of the charts today. Let me just briefly get into the compounding of that type of composition and then I will answer the question.

There are three factors to be taken into account. UV screening is number one. That's taken care of with either adequate quantities of titanium dioxide or the proper color pigment to act as a screen. Second, are the reinforcing fillers, and third the low temperature plasticizers. The silica-type fillers such as Hi-Sil 233 at the 15 to 30 part level do a nice job. The plasticizers used are normal esters, to date. For these compositions which don't

need flame resistance, dioctyl sebacate does one of the best jobs. Phosphate plasticizers are used where you do have a flame resistance test to meet. With that type of composition, you can obtain tensile strength of the coating compositions in excess of 1500 psi which would be adequate for most purposes.

We do not have as yet too much experience on long-term weather exposure with these compositions. Based on laboratory data and a tieback to our years of experience with neoprene and the same type plasticizers, I doubt that you will see very much change in low temperature properties over a long period of time. Does that answer the question satisfactorily?

Voice: Yes.

Chairman Backer: I'd like to direct a few questions toward Mr. E. V. Painter. Dr. Platt was not feeling too well when we finished our committee meeting last night and he asked Mr. Painter, who worked with him on the tear resistance problem, if he'd answer some of these questions. So, I will ask E. V. Painter of Johnson and Johnson to take over a couple of Dr. Platt's questions.

This is one from O. D. Schumann, American Enka Corporation: What work has been done concerning the possible difference in adhesion requirements due to fiber modulus and elongation levels in order to preserve maximum tear strength in the coated fabric?

Mr. Painter: I think that Mr. Corry touched on this matter in an earlier question. The work done at the Fabric Research Laboratories for the Quartermaster Corps, when I was there, indicated lubrication of the fabric and design of the structure so that the yarns would not be restricted in their movement by the coating produced a higher tear strength. I think that Dr. Platt's presentation made that fairly clear -- how the formation of the del depended a lot on the yarns moving into it. Now, adhesion requirements of the coating to the fabric are in direct conflict to that

desire; therefore, the type of coating bonded to the fabric and the stiffer the coating, the more the yarn movement is impaired.

Chairman Backer: This question is from John B. Gregory: Will you comment on the effect of the coating on coated fabrics preventing tear initiation? Could that be a more important effect than a slight deleterious effect on the tear propagation?

Mr. Painter: I remember there were a number of independent discussions when working on this project on tear, just the Tongue Tear and Elmendorf Tear. We all agreed that the trapezoid was not really a tear test, the matter of initiation of tear, basically, has the same fabric mechanics as the propagation of the tear. It is the movement of the yarns and forming it into a distorted structure. The mechanics from there on in are involved with the restriction of the yarns from moving. The more yarns that you could move into the del at one time the higher the average tear load. We were able to calculate the pounds of energy per inch of tear from the tongue tear by integrating the area under the load application diagram shown by Dr. Platt and equating that to the Elmendorf Tear. The fabric was the same. What I am saying is that once you got a small pinhole in the coated fabric you try to develop it into a tear. You still have the same mechanics of yarn moving into del getting the maximum number of yarns, and getting the highest load. The only other point is the effect of the coating; the smoother it is, the more it will deflect some object seeking to initiate the tear.

Chairman Backer: I have a comment from a fabricator which I think should be read into the record. I think it is pertinent to the coverage of this conference. The comment is made by Don Shingler. He says:

"I represent a fabricator and it appears this type of meeting is very excellent. However, I should like to see, as an addition to this conference perhaps on a day following, a meeting of your seven

classes of attendance in more of an end-use fabricators discussion.

"Our principle desire is to have available fine fabrics intended to maximum performance, but, by the same token, to have working inventories of best fabrics. We need more information on end usage techniques, on application to stitch-room techniques, etc. We feel a meeting might be interesting to key fabricators if it were to encompass fabric problems in relation to problems of turning yardage into end uses.

"I think this is one area where we had fabricators participating in the discussion but we did not lean so far in that direction as to have a formal talk on fabrication problems. I think that could be a follow-up conference."

Chairman Backer: I have a question directed to Mr. Keene but I believe he has left to catch a plane. I have asked Mr. Haas if he would answer it. It relates to abrasion testing. Would you like to read the question Mr. Haas?

Mr. Haas: The question is from Mr. L. R. Looper, Edmont Manufacturing Company: Realizing that all abrasion machines have their drawbacks and also realizing that manufacturers of coated fabrics must have some test method for screening coated samples, what instrument available today gives the greatest reproducibility?

Well, I took part with Mr. Keene in some of these round robin tests, not only the one he mentioned but several others. I agree with what he says about the reproducibility of results. Mr. Robbins from Hood Rubber Company can substantiate this. Today, the Stoll Machine seems to be favored. However, it is our feeling that refinements should be made. Refinements should also be made in the duPont Scrub Tester which is not only suited to service work

but also for control work in the plant. It has not been standardized to the point where the results from one laboratory equal those produced in another but that is also true of all other abrasion machines.

We have found the duPont Scrub Tester to be one of the most valuable pieces of testing apparatus available today for the testing of coated fabrics. For factory control work it evaluates scrub resistance, flex-resistance, adhesion of coating to fabric, abrasion resistance of a different type from that evaluated on the Stoll, Wyzenbeek, or Tabor, and in the case of organisol and plastisol coatings, a measure of the degree of fusion of the vinyl compound. If it could be engineered, modified, improved, and standardized to a point where results could be reproduced with a good measure of uniformity from one machine to another, it would undoubtedly prove to be one of the most useful machines available to the coater and would replace many of the machines now used to obtain highly questionable results.

Chairman Backer: I have two questions for Mr. Pike. One is anonymous. When will 840 denier 140 filament, Type 305 nylon be commercially available -- badly needed?

Mr. Pike: There is no positive answer we can make at this time. We have succeeded, experimentally, in making some heavier deniers in the 210 I talked about yesterday afternoon and we may have made experimental 840 denier yarn but I have no way of knowing how far that has gone.

Chairman Backer: One more question. This is from Mr. Hyman, Herculite Protective Fabrics: To what extent are quality controls applied, effecting standardization of synthetic yarn production released to weavers, especially with regard to above-mentioned performance characteristics? He indicates dimensional stability; susceptibility to ultra violet degradation and flame resistance. Secondly, what recommendations or suggestions can be offered

to the coater who wishes to further reduce or minimize product variance regarding practical and appropriate tests and test methods that could be economically adopted on a random sample basis for incoming quality inspection of synthetic yarns comprising the fabric?

Mr. Pike: I don't believe there is any answer to Mr. Hyman's question. Of course, as any yarn producer does, we maintain close quality control over our yarn production. The techniques we use for such controls are of course matters of industrial secrecy and we'd be the last to admit that our yarns are anything except highest quality, which they are.

Chairman Backer: It may be some of the coating people might like to suggest an answer to this last question from the coater's point of view. But I think we will have to table the matter for now. It is a difficult question and is a broad subject in itself.

I have a question for Mr. Grubb from R. R. Lewis: Shouldn't the Armed Services use multiple ply fabrics, one straight and one bias coated on all surfaces instead of single ply, single coated fabrics?

Mr. Grubb: I don't know. I have not seen that type of fabric.

Mr. Lewis: For life vests. That's the end item referred to.

Mr. Grubb: There again, I don't know. I'd like to see the material and evaluate it. I would like to have the performance of the material speak for itself.

Chairman Backer: This is one for Dr. Kennedy: Is Vapotex coating still being used and considered satisfactory in spite of the poor abrasion resistance mentioned by you?

Dr. Kennedy: We are not using Vapotex. We have re-examined it recently during the last year with the hopes of making use of it. I believe that the Air Force is using it in some of their outfits, in the exposure suits, I believe. I don't know of any plans on our part to do anything further with it at this time.

Chairman Backer: That constitutes the final written question received. There were one or two questions we didn't attempt to answer because the pertinent speaker had to leave early. Our schedule now affords an opportunity for questions from the conference floor.

Mr. Schlatter: We have heard a very excellent paper on the tear resistance of the base fabric and what affects the tear resistance of the base fabric, but we have heard relatively little about what are the principle causes of tear in actual use. I'd like to ask Dr. Kennedy: Can the physical properties of the coating be related to the tear strength for military garments in the field or the tear strength of attendant material or tarpaulins in the field?

Dr. Kennedy: That's a good question. I think that the fundamental thing that should be understood about our use of the fabrics, coated or otherwise, is that we regard the failure from tear as probably the first type of failure that occurs. Tear strength of the fabric is much lower than breaking strength and if the fabric starts to fail, it is going to start to fail by some type of tear. I should have added tear and certain types of abrasion. For that reason, tear is very critical.

Now, as to whether something can be done about the fabric coating to minimize tear, the presence of the coating does help to prevent snagging. In that respect, it is a plus advantage. That applies to the poncho, raincoat, and things of that sort. There are, still, occasional tears that can be started by a semi-puncture or a snag of some kind -- the stiffer the fabric, the more susceptible to tear. As I mentioned yesterday, in the case of tarpaulins, if you have a very flexible fabric, it will tend to pocket and accumulate more water and be more susceptible to a tear and puncture by some sharp point than a stiffer fabric. The answer is to reinforce it more. Then, if you follow that principle you wind up with a very

heavy type of fabric such as we have with the duck, which has a high tear strength because of its sheer brute force.

Mr. Frishman: Knitted fabrics are very good in tear strength, why haven't they been used to a greater extent in coating?

Mr. Haas: One very definite reason -- they are far more difficult to coat, particularly to coat to a waterproof state and, of course, they do lack dimensional stability. It generally requires a far heavier coating and is far more difficult.

Chairman Backer: I understand the synthetic or artificial type leathers are made just that way; that is, a vinyl film laminated to knitted fabrics.

Mr. Haas: That's true. Vinyl film coatings are laminated to the knit fabrics and are relatively heavy and in most applications today you're looking for as light a weight as possible and the easiest. The vinyl coatings to knit fabrics themselves are very difficult to apply.

Mr. Green: (Wright Field) I don't know if this would be the right place but I have a unique interest right now in connection with the high altitude balloons of the Air Force. I refer to balloons that will go up to 100,000 ft. More often than not, the launchings had to be called off because these unsupported plastic balloons tore and we had to wait until we got a new helium supply. Do you think it would be possible to either laminate a film or coat an extremely lightweight knitted fabric of the order of five denier, 60 gauge nylon hosiery material or some such material to add a little tear resistance to such a balloon material? I would like to hear if there is any chance to ever achieve that.

Mr. Haas: I am not certain that I understood everything you asked about, in general, I am able to state that if you were to laminate knitted fabrics directly to a lightweight monofilament type of material there will be a series of adhesion problems. In the stretching

of the yarn to bring it into place, the coating would tend to loosen. We have successfully coated a knit fabric for the Navy, using Helanca yarns but, don't forget, Helanca has a definite crimp and bulk which assist in obtaining adhesion. A fabric like that can be coated and you can obtain good adhesion without the use of adhesives. That is not true, however, with the very lightweight nylon fabric which, I believe, you mentioned.

Mr. Green: We have a basic problem of not increasing the weight of these high altitude balloons so much that we would have to go to a bigger balloon and need more helium.

Chairman Backer: The weight factor is what works against the thickness of the film.

Mr. Green: We are concerned with the fact that too many balloons are wasted and it takes so long to get new balloons. If we could reinforce the film, it would help. I believe they are only two mil in thickness. They have used mylar, vinyl films, and all sorts to add a little bit more tear strength so they don't rip so easily.

Chairman Backer: I think this is a question you can discuss further with Mr. Haas after we finish the formal session. Maybe Mr. Schafer in the laminating field might have something to suggest. I think you have to see these balloons spread out on the cutting room floor to appreciate the immensity of the material requirement.

According to our schedule we must now terminate the questions. On behalf of the Committee on Textile Fabrics, I thank you all for being such an attentive audience. I would like to thank, also, the members of the Quartermaster Corps, particularly Dr. Kennedy and Mr. Weiner for their very excellent hospitality. My appreciation goes to the speakers who went to such great effort in collecting their material and presenting it in a manner which proved so interesting to all seven categories of our audience. I now turn the meeting over to Dr. Kennedy.

Dr. Kennedy: Thank you very much, Dr. Backer. Ladies and gentlemen, it has been a pleasure to have you here. The meeting exceeded our expectations. We did not anticipate so much interest in the industry and this expression justifies our past efforts. The stimulus from this conference should be productive of many improvements in materials for future military uses.

NATIONAL ACADEMY OF SCIENCES NATIONAL RESEARCH COUNCIL

The National Academy of Sciences National Research Council is a private, nonprofit organization of scientists, dedicated to the furtherance of science and to its use for the general welfare. The Academy itself was established in 1863 under a congressional charter signed by President Lincoln. Empowered to provide for all activities appropriate to academies of science, it was also required by its charter to act as an advisor to the Federal Government in scientific matters. This provision accounts for the close ties that have always existed between the Academy and the Government, although the Academy is not a governmental agency.

The National Research Council was established by the Academy in 1916, at the request of President Wilson, to enable scientists generally to associate their efforts with those of the limited membership of the Academy in service to the nation, to society, and to science at home and abroad. Members of the National Research Council receive their appointments from the President of the Academy. They include representatives nominated by the major scientific and technical societies, representatives of the Federal Government, and a number of members at large. In addition, several thousand scientists and engineers take part in the activities of the Research Council through membership on its various boards and committees.

Receiving funds from both public and private sources, by contribution, grant, or contract, the Academy and its Research Council thus work to stimulate research and its applications, to survey the broad possibilities of science, to promote effective utilization of the scientific and technical resources of the country, to serve the Government, and to further the general interests of science.

ADVISORY BOARD ON QUARTERMASTER RESEARCH AND DEVELOPMENT

Recognizing the need for independent scientific advice on his research and development program, the Quartermaster General, in 1943, requested advisory services and for this purpose established a formal contract with the Academy Research Council. To fulfill the terms of this agreement, the Committee on Quartermaster Problems was organized by the Academy Research Council under the Division of Engineering and Industrial Research. In 1948, the scope of the Quartermaster advisory activity was broadened, and the committee was reorganized as the Advisory Board on Quartermaster Research and Development.

The objective of the Advisory Board on Quartermaster Research and Development and its committees, by providing scientific and technical advisory services to the Quartermaster Research and Engineering Command, Natick, Massachusetts, is to aid the Quartermaster Corps in the most efficient achievement of the Corps mission—protecting, feeding, and supplying the combat soldier in any future emergency.